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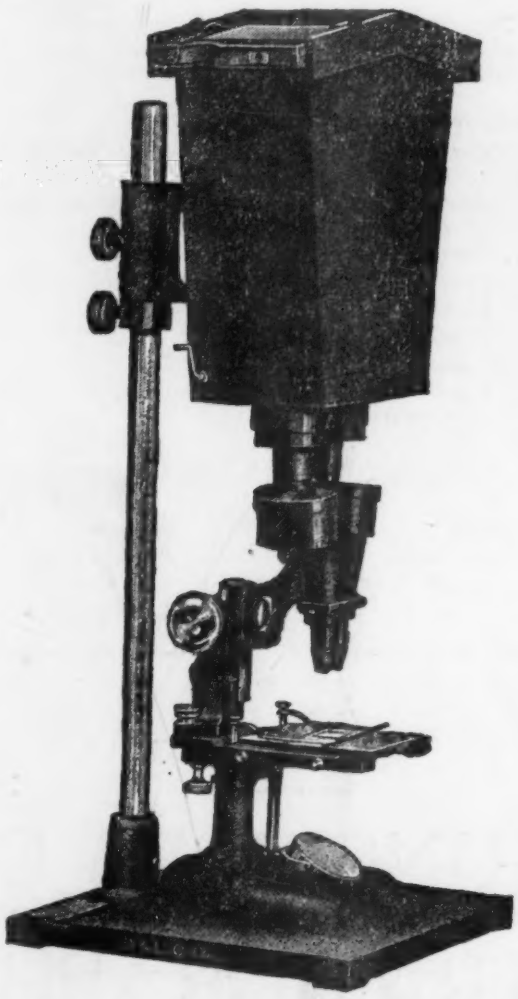

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SOME RELATIONSHIPS OF CHEMISTRY AND LIFE[1]

ABOUT the middle of last century Huxley and his co-workers clearly recognized the place of science in education, and the relation of both to life, and urged upon the world the necessity of scientific knowledge. Meanwhile, the schools and colleges have tried the experiment and have been convinced, but it has taken the present war with its terrible toll of death and destruction to focus the attention of the masses in a way which a century of reasoning has failed to do. This is not the place to discuss either of these experiences in detail, and I shall content myself by giving the conclusions of one competent witness who has watched the entire progress of the experiment.

After more than fifty years of continuous study of the education problem, Ex-President Eliot, of Harvard, concludes that the present generation is characterized by two strong desires. The first is a desire for a sound knowledge of the facts, and the second is an intense desire to be of service to mankind. If these conclusions are well founded, education must provide for their realization if it is to be successful in the broadest sense. This program, of course, is but another way of stating the scriptural text, "Know the truth, and the truth shall make you free." For the purpose of this address no better text could be found, for these words sum up as clearly as can be done the place of the scientific method in the learning process, and the relation of science to life as a whole.

[1] Address delivered on the occasion of the dedication of the chemical laboratory of the University of Oklahoma, January 26, 1917.

The necessity of realizing these relationships in everyday life has been persistently urged for two generations by men of science, but it has taken the present world crisis and its consequent interruption of our commercial relations to show how much more should have been done. The preparedness programs of this and other nations, as well as the utterances of thoughtful men in responsible positions in various walks of life, bids us hope that the lesson has now, in a measure, been learned. In a recent address before the British Association for the Advancement of Science an able chemist says:

> The press bears witness through the appearance of innumerable articles and letters that the people of this country have begun to perceive the dangers that will inevitably result from a continuance of their former attitude, and to understand that in peace, as in war, civilization is at a tremendous disadvantage in the struggle for existence unless armed by science; and that the future prosperity of this empire is ultimately dependent on the progress of science and very especially of chemistry. If, as one result of the war, our people are led to appreciate the value of scientific work, then perhaps we shall not have paid too high a price. (The same view has been expressed by many eminent American chemists.)

A similar note of warning is sounded by a continental writer in discussing the question of whether we shall have a precarious or a lasting peace. He says:

> It would be a dangerous mistake to suppose that any readjustment of frontiers could afford a sufficient guarantee for future peace, or that war indemnities, protective tariffs and the like could oblige the peace-breakers to renounce their schemes. . . . At the future (*peace*) congress, among the seats reserved for the delegates of the Great Powers, one seat should remain vacant, as reserved to the greatest, the most redoubtable, though the youngest of Powers: Science in scarlet robes.[2]

Before taking up a discussion of the relationship of chemistry and life, it may be worth while to inquire as to the general attitude of the public toward the work of the chemist. If you ask the first person you meet, or if you get the opinion of the newspaper man or other influential citizen, about the work of the chemist, he is apt to tell you that the chemist is a man who can analyze substances, and detect falsification in them; but he is not likely to tell you that the chemist has any important relationship to the commercial development of the enterprise in question. How many in this audience, for example, think of the chemist when they pour their "Karo" on their hot cakes at breakfast, when they read the headlines of the daily paper and learn that a wireless message has been flashed across the ocean; when they step into an automobile to start the day's work, or when, the work completed, they while away the time of the evening watching the screen in some motion picture show? Nevertheless, in the successful working out of each of these the chemist has played an important and, in some cases, a vital part, but I have not time here to give particulars.

Let me give you a concrete example of what I mean. Whenever one thinks of the Panama Canal one's thoughts turn at once to the chief engineer, Col. Goethals. He is the one to receive the medals, the honorary degrees, the thanks of Congress, the promotion to higher rank in the army, and finally to be named governor of the Canal Zone. Do not misunderstand me: I am not complaining of this recognition of the man's undoubted merit, because Goethals was unquestionably the moving spirit in the undertaking, and certainly worthy of all the honors that have come to him. But when we come to survey the case a little more closely, we see that there are at least three other factors for neither of which Goethals was personally responsible, but without the support of any one of which he

[2] Reinach, S., *Nation*, June 15, 1916.

would have been absolutely helpless. The first of these is the health of the laborers. The French undertook to build the canal years ago, and while their failure was brought about by several causes perhaps one of the most important was the fact that the men could not live in that part of the world and retain their health. Yellow fever and malaria were everywhere, and it was but a matter of time when one must be attacked by one or both of these infections. It has been stated that the building of the railroad across the Isthmus meant the death of a man for every tie that was laid. But man can live in Panama now with perfect safety, so far as yellow fever is concerned, and this is due entirely to discoveries with which Col. Goethals had nothing to do. Dr. Gorgas was in immediate charge of the work of sanitation, but it was kerosene, the product of the chemist, which was sprayed on the stagnant pools, and which checked the development of the mosquito.

In the second place, the penetration of Culebra, as well as the remainder of the blasting necessary, would have been impossible without the powerful explosives of the chemist. The gun-powder, dynamite, blasting gelatin and similar substances are all products of the chemical laboratory.

In the third place, let us suppose that the development of the mosquitoes has been checked, that Culebra has been pierced—the work is only half done. It is necessary to control the level of water in the canal, and this, under the conditions imposed, can be done in only one way, namely, by the construction of locks and dams. For these some material stronger than wood and less easily corroded and destroyed than iron must be used, and this is found in the chemist's cement. As is well known, thousands of barrels of this material were used in the work.

Finally, when the canal is complete and ships are passing back and forth through it, there is comparatively little safety until it has been fortified. The chemist's powder and steel must stand guard over it as they do over every treasure we own, or we should not be able to retain it as a national possession.

Cases of this kind could be multiplied indefinitely, but I must not take your time to do so. On the other hand, the Panama Canal is so remote that many persons do not think of it as having any bearing whatever on their daily lives. But the question of food and war munitions at this time can hardly be misunderstood by any, and it remains merely to show the relations of chemistry to these to convince the most indifferent. A detailed discussion of even these would tax your patience, I fear, therefore I shall limit myself to the consideration of a single element, viz., nitrogen.

It has long since been proved that nitrogen is an essential constituent of the food of all living beings, and that, in general, it may not be assimilated if taken directly from the air where it is present in the free form. It must be combined with one or more other elements. As one begins the study of nitrogen in a chemical laboratory, he finds what at first sight appears to be a relatively uninteresting element. It has neither color, odor nor taste, is but slightly soluble in water, and does not readily combine directly with other elements. But in combination it is a constituent of many different substances of the most varied characters. It is present in some of the most delicate of perfumes as well in substances whose odors suggest utter vileness. It is a constituent of various fibers (wool, silk, artificial silk) used in our clothing, and also of the aniline dyes which enhance their beauty and value. It is present in the most potent of medicines and in the most deadly poisons. As gunpowder it drives our bul-

lets, as dynamite it explodes our mines, and as cyanide it extracts our gold. Under the general name of protein it is an indispensable element of animal food, and as animal waste, it is returned to the soil as food for plants. Thus, nitrogen not only gives life, health and prosperity, but it is the most terrible element of death and destruction known to modern warfare.

In considering nitrogen as an element of food, we may note in passing that the normal adult human body requires a certain amount of the element every 24 hours, and that this must be supplied in the form of meat, eggs and various vegetables, all of which are either directly or indirectly products of the soil. Now, every one knows that continual cropping causes a soil to become poor, and chemical analysis shows that the change is due, in part, to the loss of nitrogen. Fertilizers are applied to the land to increase the yield.

The problem will become clearer if we take another view. There was a time when fewer people lived in cities, and when this depletion of the soil was largely restored by the refuse from farm animals and even from man himself, from which it follows that the greater portion of the nitrogen removed as food for animals was returned to the soil in some other form available for plant growth.

We may next consider the complications that arise in dealing with such aggregates of population as our large cities. Sustenance must still be drawn from the soil, and since nitrogenous waste is no longer returned to the land it is clear that the latter is continually being depleted. A single example will illustrate the point. The sewage of the city of London has an estimated annual value of $100,000,000 as fertilizer, and that of any other city would represent an amount corresponding to its population. These drains, of course, must in some way be accounted for if the soil is to continue to produce. What, now, has science done to relieve the situation?

When chemical analyses of soils and crops had clearly defined the problem and had told the story of nitrogen, a search was made for some material that could supply the deficit. First, natural guano, as it is called, deposits consisting largely of the dried excrements of birds, and found in such arid districts as Peru, was obtained in as large quantities as possible. But material of this kind was limited in amount and is now practically exhausted.

Next, the chemist saw that the waste liquors of the gas works contained combined nitrogen that could serve as plant food, and we are now using in the United States $20,000,000 worth of ammonium sulphate as fertilizer per year. This, again, is limited because in this country about 80 per cent. of the coke is made in the wasteful "beehive" oven in which the vapors are simply burned on the spot. The ammonium sulphate derivable from those vapors in 1911 could have been sold for $24,000,000, to say nothing of the other compounds present. But gas plants can not be operated economically for the ammonium sulphate alone, and our coal beds are not inexhaustible, which shows that some other nitrogen supply must be found.

The third source of plant nitrogen is the Chile saltpeter bed, from which millions of tons of sodium nitrate have been taken as fertilizer to different parts of the world. This supply, also, is limited. Indeed, conservative estimates indicate that the deposits will be exhausted within a relatively short time, which means that man must solve the nitrogen problem in some other way, or he must eventually starve. The necessity for research in this field has been urged for many years, and it is now in order to ask what chemistry has done to relieve the situation.

It has already been stated that nitrogen

does not readily combine with other elements, and that animals and plants, with very few exceptions, can not use free nitrogen as food. But the free form is plentiful, since it makes up about four fifths of the atmosphere, while the greater portion of the remainder is oxygen. The specific problem, then, is to cause those two gases to unite, or to find some other way of "fixing" the nitrogen. This has been accomplished, and while the history of the commercial process now in use is full of interest, it must be passed here with mere mention. It should be noted in passing that Cavendish, an English chemist, showed as early as 1785 that nitrogen and oxygen could be made to unite under the influence of the electric spark, and that the product would react with water to give nitric acid. At that day, however, electricity was regarded as a mere toy, and no one dreamed of the possibilities locked up in that interesting though, to the average person, seemingly useless, laboratory experiment.

In 1898, Sir Wm. Crookes aroused interest in this problem again by calling attention to the future exhaustion of the Chile saltpeter beds, and urged a study of methods for fixation of nitrogen. In 1902, Bradley and Lovejoy, two American chemists, published an account of the commercial application of the Cavendish experiment mentioned above, while to-day the manufacture of nitric acid by that process in Norway is a business in which more than $30,000,000 is invested. Immense sums have been spent in its development in Germany and elsewhere.

At present, the manufacture of calcium carbide, so largely used in the production of acetylene for lighting and heating purposes, offers an important method for fixing nitrogen. The manufacture of the carbide was begun in this country several years ago and is now one of the leading industries of Niagara Falls. Frank and Caro, German chemists, found that the carbide could be made to combine with nitrogen in such a way as to produce a valuable fertilizer. The nitrogen it contains can readily be converted into ammonia, and from the latter nitric acid can be prepared. As a matter of fact the Germans are now producing 600,000 tons of the carbide annually in order to supply, through the reactions indicated, the nitric acid required to make explosives for the war.

In this brief and superficial fashion, I have tried to make it clear that the preparedness which the nations demand is twofold—agricultural as well as military—and that, in essence, both are largely chemical. Cheap fertilizer must be furnished in times of peace, and nitric acid and other materials for explosives in times of war. So much for the formulation of the demand. The real problem is to furnish the means by which this program can be successfully carried through.

So far as the chemical part of the program is concerned, two specific requirements must be met. First, there must be adequate training in the fundamentals of chemistry, and second, there must be opportunity for chemical research. The first is conceded by everybody, but many highly intelligent educated people do not understand research, and therefore call it theoretical and impractical. The cry is for applied science, for something practical. They fail to recognize the fact that there can be no applied science until there is science to apply. It is not strange that Huxley, with his extraordinary precision of thought and remarkable command of language, long ago pointed out that what people call applied science is nothing more than the application of the methods of pure science to particular classes of problems. Some one must patiently and laboriously determine the facts and formulate the principles before there can be any commercial

application of them; and, whether we recognize it or not, the world is waiting on the research worker.

If time were available it would be easy to show that practically all the great commercial successes rest upon principles formulated by research workers who, in many cases, labored solely for the love of truth, without any expectation that their work would immediately benefit mankind. But no one can tell at what instant some such observation may become of immense importance. I beg your indulgence to call attention to a few cases. Was Röntgen thinking of the extraction of bullets, the reduction of dislocated limbs or the setting of broken bones when he discovered the X-rays? By no means. Or Helmholtz, did he have in mind the prevention and cure of eye diseases when he worked out the principle of the ophthalmoscope? Not at all. Was Cavendish, to whom I have already referred, thinking of providing food and war munitions for the future when, 132 years ago, he read before the Royal Society his paper on the fixation of nitrogen? I think not. No one will doubt the great practical value to the human race of Pasteur's researches, but it is proper to point out here that he began by the study of the asymmetry of crystals, and that he became a bacteriologist through his attempts to disprove the doctrine of spontaneous generation. Scores of cases could be cited to illustrate the point, but the lesson is, learn the facts, and the applications will be forthcoming.

The expenditure of public money for the erection of the splendid building we are assembled to dedicate is an expression of continued confidence in the leaders in charge of our educational interests, and a pledge that the necessary equipment for the future shall be provided.

It is a pleasure to me to come here to-day and have a part in the dedication, not merely because of my interest in the educational welfare of our state, as a whole, but more particularly because of the opportunity it gives to emphasize the claim of science in general and chemistry particularly in connection with the problems now confronting the world. Interest in the study of chemistry has been steadily increasing for many years, but its importance has been emphasized by the war in a way that could not have been done otherwise. The University of Oklahoma is to be most heartily congratulated on having completed at this time a laboratory so carefully planned and so well equipped, as well as upon the work of its department of chemistry in the past. With the extra space and facilities offered by the new building, both the university and the state may confidently look forward to greater things in the future.

L. Chas. Raiford
Oklahoma Agricultural and Mechanical College

SCIENTIFIC EVENTS

ENGLISH VITAL STATISTICS

The annual report of the registrar-general on births, deaths and marriages in England and Wales for 1915, as summarized in the London *Times*, is remarkable for the number of previous "records" which are broken. Thus the marriage rate was the highest on record; the birth rate the lowest on record; the death rate from typhoid fever was the lowest on record; that from influenza the highest since 1900; and that from measles the highest since 1896. Again, the age rates of bachelors marrying spinsters and spinsters marrying bachelors were both the highest on record. Finally, the increase of boy babies over girl babies from July, 1915, to June, 1916, was the highest on record for 50 years. The estimated infant mortality rate for 1916 is the lowest on record.

The marriage rate was 19.5 per 1,000, being 3.6 above the rate in 1914. The provisional figures for 1916, however, indicate that what has been described as the "boom" in marri-

ages is passing; they suggest a return to the average experience in 1905–14. The birth-rate was 22 per 1,000. This is 3.5 below the average for the preceding ten years and 1.8 below the rate in 1914. The rate in England and Wales, however, compared "very favorably" with the experience of other belligerent countries. The provisional rate for 1916 is lower still—21.6 per 1,000.

The infant mortality during the year was 110 per 1,000 births. This is five per 1,000 above the rate in 1914, but is below the average of the years 1905–14. The provisional infant mortality rate for 1916 shows a fall to 91 per 1,000, the lowest on record. The civilian death-rate was 15.7 per 1,000, which is 1.2 per 1,000 above the average for the previous 10 years. Various factors, however, affect this figure, including the withdrawal of young men from civilian life. Most of the principal causes of death show increased mortality, but scarlet fever, typhoid fever and diarrhœal diseases are exceptions to this rule. The disease, cerebro-spinal fever, "spotted fever," showed an abnormally high death-rate. There was a remarkable decrease in male suicides. The position with regard to tuberculosis remained serious. There was a marked increase among males and a slight increase among females. These rates refer only to the civil population and are swollen by the fact that healthy males have been taken away from civil life in great numbers.

There were 360,885 marriages, an extraordinary number. The average age of bachelors marrying spinsters was 27.33 and of spinsters marrying bachelors 25.47, these being, as stated above, the highest recorded in each case. The number of births recorded was 814,614, of which 36,245 were illegitimate. Males numbered 415,205, females 399,409, the ratio being 1,040 to 1,000. This ratio for the whole year does not represent the true situation as regards "war babies." The March quarter, for example, which was unaffected by the war, showed a ratio of 1,032 males to 1,000 females. The December quarter, on the other hand, showed a ratio of 1,044 males to 1,000 females. For 1916 the ratios are known to be: March quarter, 1,050 males to 1,000 females; June quarter, 1,051; September, 1,045; and December, 1,050.

For the year from July 1, 1915, to June 30, 1916, that is for the first complete year during which the births registered have been fully affected by war conditions, the ratio is 1,047 males to 1,000 females. This figure is considerably—so far as males are concerned—above any recorded during the preceding 50 years and approximates to the European rate which has for many years been in excess of our own. A rise in mortality among the aged of both sexes has occurred. It is a feature which has appeared in the statistics of other belligerent countries and may be a reflex of the unusual stress and anxiety of the times.

THE COMMITTEE ON COAL PRODUCTION OF THE COUNCIL OF NATIONAL DEFENSE

THE Council of National Defense has appointed Mr. Francis S. Peabody, chairman of and with authority to appoint a committee on coal production, representative of the coal-producing districts throughout the United States. It is the intention that the members of this committee shall act as chairmen of subcommittees to be appointed by them in their respective districts.

The committee convened in Washington on May 9, at which time, in addition to the members of the committee, there were present Secretary of the Interior Franklin K. Lane, Mr. W. S. Gifford, director of the Council of National Defense, and Mr. Bernard M. Baruch, chairman of the committee on raw materials, minerals and metals, of the advisory board of the Council of National Defense, from which an outline of the proposed scope of the committee's work was received.

In approving the appointment of this committee and laying before it the work that it was expected to do, Secretary Lane referred to the cooperative spirit already shown by the business men of the country in this mobilization of the resources of the United States.

> It would surprise the nations of Europe to know how intense is the spirit of loyalty on the part of our business men and capitalists. . . . You are at the very root and foundation of the great industry

—the war industry—that presents itself on the other side of the water. . . . Now, there are two ways of dealing with a problem of this kind. One way is by the hearty cooperation of the men already engaged in the industry. The other way is by compulsion. My experience in the Interstate Commerce Commission led me to believe that the larger men in the railroad industry had quite as much vision as I had, and if I could show them the importance of an occasion they would try to meet it. So, instead of resorting to compulsion, instead of taking over mines and great operating plants we are endeavoring to put you men at your best. This war is a challenge to us.

The chairman of the committee writes:

Notwithstanding the increased production of coal from practically every district, the increasing requirements to meet the needs of all classes of industry, as well as for the comfort and welfare of the people and the transportation of troops, munitions, food and other products, together with the supplying of our allies, and for our national protection—all these demands are liable to surpass the capacity of our mines unless the full cooperation of the mining, transporting and distributing agents of this country is secured. This emergency requires not only the development of the highest efficiency, especially on account of a diminished supply of labor used in the production of coal, but also in more comprehensive methods of cooperation by the coal producers with the transporting and distributing agencies, so that not only a full production will be secured, but also that this production finds its way over our railroads into those centers where the most urgent need exists. If the demand for this product continues to increase it may be necessary that active steps be taken to so far as possible confine the distribution and use of it to those activities which are more nearly vital to the welfare and protection of the nation. That this may not effect an unnecessary hardship upon the domestic welfare of our people it is necessary to promote the closest cooperation, and because of the duty laid upon us to promote this welfare we urge upon you that you cooperate with this committee in its efforts to promote the largest production, the most equitable distribution and the highest use to produce the best economic results. No doubt an emergency exists, but it is the belief of this committee that with your hearty support and the assistance of the public in conserving supply, sufficient fuel can be had to meet public necessity.

FOOD EXHIBITS AT THE AMERICAN MUSEUM OF NATURAL HISTORY

Many foods, hitherto not eaten by the people of the United States, or which have only a limited vogue, are shown at the Food Values and Economies Exhibition opened on May 23 in the American Museum of Natural History.

An especially interesting feature of the exhibition is the division devoted to unutilized seashore foods, such as filet of shark, gray fish, mussels, skate, many kinds of edible seaweeds and periwinkles. The history and usefulness of the king of American cereals—corn—is graphically demonstrated. There are numerous products of corn and also cornmeal dishes and preparations.

The values by calories of portions in the popular restaurants are visualized and there are specimen meals suitable for serving in the home. How the population fares in lands beyond the sea will be shown by samples of war bread and of the rations prescribed by European food dictators. The housewife may also obtain from this exhibition many practical suggestions as to how to stop the leaks and to promote table economy. Several hotels of the city are to exhibit new dishes specially adapted for the conditions of the present day and from them many helpful hints may be obtained by the general public.

The exhibition will be open for about one month. It was introduced by a special meeting devoted to conservation for war, held in the auditorium of the museum on Wednesday. According to the program the president of the institution, Dr. Henry Fairfield Osborn, presided and addresses were to be delivered by Mr. George W. Perkins, chairman of the Mayor's Food Commission; Dr. Graham Lusk, professor of physiology, Medical College of Cornell University; Dr. Hermann N. Biggs, New York State commissioner of health; and Dr. Walter B. James, president, New York Academy of Medicine.

SCIENTIFIC NOTES AND NEWS

Dr. Charles R. Cross, Thayer professor of physics at the Massachusetts Institute of Technology, will become professor emeritus at the

end of the present year. Dr. Cross has been professor of physics at the institute since 1875.

AT a testimonial dinner given by the Philadelphia County Medical Society to Dr. James Tyson on his retirement after fifty-four years of practise on May 11, Dr. Hobart A. Hare was toastmaster and addresses were made by the following speakers: Dr. Henry D. Jump, president of the Philadelphia County Medical Society; Dr. Abraham Jacobi; Dr. William H. Welch; Dr. James W. Holland, and Dr. Edward Martin.

DR. T. BRAILSFORD ROBERTSON, professor of biochemistry and pharmacology in the University of California, has donated to the regents of the University of California his patents for the growth-controlling substance tethelin which he has succeeded in isolating from the anterior lobe of the pituitary body and which has been employed to accelerate repair in slowly healing wounds. The proceeds which may accrue from the sale or lease of these patents are to constitute a fund which will be entitled "The University of California Foundation for International Medical Research" and which will be expended in the furtherance of medical research, preferably in the physiology, chemistry and pathology of growth.

THE Société de Géographie has awarded its highest prize, the Conrad Malte-Brun Gold Medal to Dr. John H. Finley, president of the University of the State of New York, in recognition of "the exceptional interest and high merit of his volume, 'The French in the Heart of America.'" The Commission de Géographie of Quebec, with the approval of the Minister of Lands and Forests, has named a new township in Gaspé, P. Q., in honor of Dr. John M. Clarke, state geologist of New York in recognition of his scientific writings on Gaspé and especially of his book "The Heart of Gaspé."

PROFESSOR WM. BULLOCK CLARK, of the Johns Hopkins University, has been appointed by the governor of Maryland a member of the State Defense Council.

THE executive committee of the Entomological Society of America has commemorated the appearance of the fourth and final volume of the Carnegie mosquito monograph by electing Frederick Knab a fellow of the society.

THE Institute of Chemistry, London, has presented a silver bowl to Mr. R. B. Pilcher, registrar and secretary, in appreciation of his twenty-five years' service.

A COMMITTEE on research to cooperate with the National Research Council has been appointed at Washington University, consisting of members of the corporation, St. Louis alumni and faculty as follows: B. M. Duggar (chairman), J. Erlanger, E. Flad, W. W. Horner, A. S. Langsdorf, E. Mallinckrodt, R. McCulloch, L. McMaster, G. T. Moore, E. L. Opie, L. Pyle, P. A. Shaffer and J. L. Van Ornum.

A RESEARCH committee has been appointed at Iowa State College at the suggestion of the National Research Council. The committee is representative of the various interests of the college and is made up as follows: P. E. Brown, professor of soil bacteriology, chairman, J. M. Evvard, associate professor of animal husbandry, L. H. Pammel, professor of botany, L. B. Spinney, professor of physics, Helen Monsch, associate professor of domestic science, Chas. Murray, associate professor of veterinary pathology and bacteriology.

A FIRM of geologists has been organized in Tulsa, Oklahoma, for consulting work, consisting of Messrs. J. B. Newby, R. E. Garrett, J. R. Crabtree and A. P. Wright.

CHARLES FULLER BAKER, professor of agronomy in the college of agriculture of the University of the Philippines, has been given a year's leave of absence, to accept under temporary appointment, the post of assistant director of the Botanical Gardens at Singapore, in charge of experimental work in tropical agronomy.

B. R. LEACH, of the Bureau of Entomology, who has been in Washington preparing manuscript and notes on the results of his investigations of the woolly apple aphis, has returned to his permanent headquarters at Winchester, Va., to resume his field duties in connection with apple insect investigations.

Frank R. Cole, scientific assistant in the Bureau of Entomology, formerly located at Washington, D. C., has been detailed to Hood River, Ore., to investigate insects injurious to strawberries and other truck crops in cooperation with the Oregon Agricultural Experiment Station at Corvallis.

Dr. L. H. Pennington, of the college of forestry of Syracuse University, has been put in charge of the white-pine blister rust survey for the State of Michigan, as the representative of the Bureau of Plant Industry. His headquarters, when not in the field, are at the department of botany, Michigan Agricultural College, East Lansing, Mich.

Thomas Clachar Brown has resigned his position as associate professor of geology at Bryn Mawr College and has taken up work in agriculture. He may be addressed at Laurel Bank Farm, Fitchburg, Mass.

Professor Edward Orton, Jr., for many years dean of the college of engineering of Ohio State University, and at present research professor in ceramic engineering, has obtained indefinite leave of absence from the university. He has been commissioned as a major in the Quartermasters Corps, Officers Reserve Corps, United States Army, and has been ordered to report for duty to Fort Sam Houston, Texas.

Dr. Bertram G. Smith, associate professor of zoology at the Michigan State Normal College, Ypsilanti, has obtained leave of absence to enlist in the Reserve Officers' Training Corps, and is now stationed at Fort Sheridan, Ill. Mr. A. G. Papworth, of the University of Michigan, is taking charge of Dr. Smith's work at the Normal College.

At its last meeting on May 9, 1917, the Rumford Committee of the American Academy of Arts and Sciences made the following appropriations:

To Professor Frederic Palmer, Jr., in aid of his research on light of very short wave-lengths (in addition to former appropriations), $100.

To Mr. David L. Webster for the salary of an assistant in connection with his research on the intensity of lines in X-ray spectra, $100.

To Professor B. J. Spence in aid of his research upon a new Color Identity Pyrometer, $75.

To Professor B. J. Spence in aid of his research upon a new and more sensitive form of radiometer, $150.

To Professor R. C. Gibbs in aid of his investigations on the absorption of organic and other solutions for ultra-violet, visible and infra-red rays, $500.

To Professor W. M. Baldwin in aid of his research on the character of chemical substances necessary to sensitize animal tissues to the influence of X-rays, $125.

The North Carolina Academy of Science at its recent meeting elected as officers for the ensuing year:

President, Professor W. A. Withers, Agricultural and Engineering College, West Raleigh.

Vice-president, Dr. J. H. Pratt, State Geologist, Chapel Hill.

Secretary-Treasurer (tenth year), Professor E. W. Gudger, State Normal College, Greensboro.

Additional Members of the Executive Committee, Mr. Bert Cunningham, High School, Durham; Mr. H. R. Totten, University of North Carolina, Chapel Hill; Professor H. C. Beardslee, Asheville School, Asheville.

Dr. Julius Stieglitz, chairman of the department of chemistry of the University of Chicago, lectured before the Nebraska Section of the American Chemical Society on the morning of April 28 and before the Nebraska Chapter of Sigma Xi on same evening. The subject of his morning lecture was "The Electron Theory of Positive and Negative Valences" and of the evening lecture "Combustion or the Electrical Theory of Oxidation."

Dr. J. McKeen Cattell gave an address on May 19 before the Twentieth Century Club at Boston on "Free speech in the university."

The annual public botanical address, under the auspices of the Botanical Seminar of Michigan Agricultural College, was delivered on May 15, by Dr. L. H. Pennington, of Syracuse University, his topic being "White-pine blister rust."

By the death of Samuel Alexander at his home in Detroit on May 15 is lost one of the old time amateur botanists, that is, a man

who worked in botany because of his ardent love of plants. Mr. Alexander was nearly eighty years old at the time of his death, but still kept up his studies in spite of illness that limited his active collecting for the past three years. For the last ten years his chief studies were on the perennial sunflowers, of which he found great numbers of forms and of which he hoped to be able to publish a monograph. He was at one time city forester for Detroit and furthered the planting and care of trees in that city at a time when there were but few voices advocating such things. He entered the Michigan Agricultural College in the early spring of 1861 but left in a few days as the first volunteer from that institution for the war.

WE learn from *Nature* that Major A. C. B. Geddes, who had begun work in natural science has been killed in the war at the age of twenty-five years. He was the eldest son of Professor Patrick Geddes.

THE death is announced of S. Tolver Preston, known for his writings on cosmical physics.

M. HENRI BAZIN, distinguished for his work on hydraulics, has died at the age of eighty-eight years.

THE sixteenth biennial Dutch Congress of Natural and Medical Sciences was held at The Hague on April 12 and following days. We learn from *Nature* that in connection with this, the geography section had organized an interesting historical exhibition, mainly of the work of Mercator and the Dutch cartographers of the seventeenth century. The chief general lecture was delivered by Professor H. A. Lorentz, of Leyden, on "Einstein's Gravitational Theory and Fundamental Ideas in Physics." From a discussion, in one of the sections, on chemical industry in Holland, it appears that the manufacture of aniline and other intermediate materials for the dye industry was started in 1916.

THE next meeting of the American Association of Pathologists and Bacteriologists will be held at Minneapolis on March 29 and 30, 1918.

THE twelfth annual meeting of the American Association of Museums was held in New York City from May 21 to 23, inclusive. The association consists of directors and curators of leading American institutions. The sessions on Monday and Wednesday were at the American Museum of Natural History. Those on Tuesday were at the Metropolitan Museum of Art and on Tuesday evening there was an inspection of the New York Aquarium and an informal smoker. On Thursday the delegates visited the Central Museum of the Brooklyn Institute of Arts and Sciences and the Children's Museum of the Brooklyn Institute. On Friday they inspected the New York Botanical Gardens. Trips were also arranged to the Public Museum of the Staten Island Association of Arts and Sciences and to the Newark Museum. An especially interesting phase of the sessions was the report of the committee on training for museum workers, which was devoted to finding ways and means of increasing the practical usefulness of museums.

The Electrical World states that as a result of the present war conditions the Manitoba branch of the American Society of Civil Engineers has organized a scientific and industrial research committee to organize and develop the natural resources in industry and science. At present this committee is listing all available research laboratories in its jurisdiction, also all men engaged in scientific and engineering pursuits and the qualifications of each man in his particular line of research or engineering. After organization is completed a study will be made of the requirements of the Province of Manitoba as regards manufactured articles, and more especially imports, with a view to supply all local demand for such material and, if possible, to provide for export, if it can be economically accomplished.

THE trustees of Purdue University have approved the organization of an engineering experiment station. This station will be employed for the supervision of engineering research. Arrangements have also been made for the extension and equipment of a high-

voltage laboratory, in which pressures as high as 500 kv. can be obtained.

UNIVERSITY AND EDUCATIONAL NEWS

Steps have been taken to insure the erection of a new building for the Indiana University School of Medicine on a site near the Robert W. Long Hospital, Indianapolis.

Professor Robert M. Yerkes, of Harvard University, has been appointed head of the department of psychology at the University of Minnesota.

At the Johns Hopkins University, Professor Edward W. Berry, associate professor of paleontology, has been advanced to be professor of paleontology, and Associate J. T. Singewald, Jr., to be associate professor of economic geology.

At the Massachusetts Institute of Technology, Dr. Charles L. Norton has been appointed professor of industrial physics. Promotions from instructor to assistant professor have been made as follows: Mathematics, Joseph Lipka and Frank B. Hitchcock; physics, Herbert P. Holnagel; drawing, Arthur L. Goodrich.

Dr. H. H. Newman, dean of the college of science of the University of Chicago (medical and premedical students), has been promoted from an associate professorship in zoology to a professorship in that department.

In the botanical department of the Michigan Agricultural College Dr. G. H. Coons has been promoted to associate professor, and Dr. E. F. Woodcock to assistant professor. Beginning with July 1, Mr. Ezra Levin, at present instructor in botany at the Kalamazoo High School, takes up his work as extension agent in plant diseases, for half his time, and assistant pathologist in the Experiment Station for the other half.

Dr. Pierre Marie has been appointed to the chair of clinical neurology in the University of Paris in succession to the late Professor Dejerine.

Fräulein A. M. Curtius has been appointed lecturer in French at Leipzig. She is said to be the first woman on the staff of a German university.

DISCUSSION AND CORRESPONDENCE

SURFACE TENSION, CAPILLARITY AND PETROLEUM POOLS

While surface tension and capillarity[1] are being discussed, the writer would like to raise the question of whether or not the material composing the tube makes any difference in the height to which the liquid rises.

It is surprising that it is not possible to settle this apparently elementary question at once by reference to any one of a score of good treatises on physics; physics is an old science, the subject of intermolecular attraction is fundamental, capillarity is discussed at length and the deductions carry conviction born of impressive formulæ. As a matter of fact, statements bearing on the point in question seem inharmonious and many of them lack clearness. One of the most convincing that the writer has seen is that of Bigelow and Hunter,[2] who say: "We have demonstrated that capillary ascension of water (and benzene) is different in tubes of different substances," and they base the assertion on experimental evidence.

This declaration accords with the writer's[3] concepts concerning capillarity. Since he is not a physicist, these concepts should come from the conclusion of physicists concerning the point or at least from well-known and unquestioned principles of physics, but as a matter of fact they are based partly upon such conclusions and principles, partly upon several years of cogitation, and partly upon the

[1] Patrick, W. A., Ostwald's "Handbook of Colloidal Chemistry," Science, N. S., Vol. XLV., No. 1,143, pp. 750–751, November 24, 1916. Kimball, Arthur L., "Negative Surface Tension," Science, N. S., Vol. XLV., No. 1,152, p. 75, Jan. 26, 1917. Becker, Geo. F., "Propulsion by Surface Tension," Science, N. S., Vol. XLV., No. 1,153, p. 115, Feb. 2, 1917.

[2] Bigelow, S. L., and Hunter, F. W., "The Function of the Walls in Capillary Phenomena," *Jour. Phys. Chem.*, Vol. 15, p. 380, 1911.

[3] Shaw, E. W., "The Rôle and Fate of Connate Water in Oil and Gas Sands" (discussion), *Am. Inst. Min. Eng. Trans.*, Vol. 51, p. 601, 1916.

results of some experiments which may seem more significant to the writer than they would to a physicist. Up to the time Bigelow and Hunter's paper was published, at least, the literature did not seem to cover the point at all satisfactorily, yet many statements and implications seem to be clear. Ramsay and Shield's classic determinations of surface tension based upon capillary rise may be cited as an example. If capillary rise is affected by the nature of the tube, their results would apparently be invalidated.

Do not three substances ordinarily play parts in capillarity, and does not the result depend on the identity of each of the substances? If water, air and glass are the substances, the water heaps up against the glass, and if the tube is of hair-like diameter there is a rise of water. Is not this due to the fact that where water, air and glass come together molecules of water are drawn toward the glass much more than toward molecules of air or other molecules of water?

The mechanics of this process seem simple, whereas it is difficult to conceive how the raising of the liquid can be a product of its surface tension alone,[4] even though the walls of the tube above the liquid have a contractile coating of adsorbed liquid or a membranous extension of the liquid in the tube.

The writer is particularly interested in the part that capillarity or differences in intermolecular attractions may play in oil and gas accumulation. In the vicinity of oil and gas pools which occupy the pores of rocks in the earth, water with various quantities of salt in solution, oil of one or more kinds, natural gas and perhaps air are in contact with each other and with various minerals. Oil and gas are found in relatively large-pored rocks, in pools which show some similarity in shape and the pressure upon them is usually several hundred pounds to the square inch. The pressure on some pools is greater than that which would be exerted by a column of water extending to the surface. May not these features be explained in considerable part by differences in intermolecular attractions?

E. W. SHAW[5]

[4] Washburne, C. W., "The Capillary Concentration of Gas and Oil," *Am. Inst. Min. Eng. Trans.*, Vol. 50, p. 830, 1915.

SYNCHRONOUS RHYTHMIC MOVEMENTS OF FALL WEB-WORM LARVÆ

RECENT discussion in SCIENCE of synchronous actions of certain animals, notably, flashing of fireflies, brings to mind a habit of the larvæ of the fall web-worm (*Hyphantria cunea*), which seems to be of the same nature. Whether it has been noted in the literature or not I am unable to say; probably it has, as it is of common occurrence. In any event a short account of the habit may not be out of place in this connection.

Fall web-worm larvæ, scattered over the outside of the web, may be seen, at intervals of from three to five minutes, to start a sharp rhythmic swaying from side to side, accomplished by raising the anterior half of the body to a semi-erect position, then moving it quickly, first to one side then to the other, through an angle of about ninety degrees. The movement is started by a few of the larvæ, but in a few seconds all the individuals in the colony will be moving in the same manner and in perfect unison. I do not have my notes at hand but, as I remember it, the movements were at the rate of about forty per minute and continued each time for from forty-five seconds to more than a minute. Even more suddenly than they start, the movements cease.

What the cause is for this strange habit is a puzzle. It seems to have nothing to do with spinning the web. Artificial stimuli failed to start them before the end of the resting interval although various means were tried. These included sounds, both musical and otherwise, made with various instruments, smoke and strong chemical odors, jarring and several other devices which suggested themselves at the time. Equally futile were attempts to stop the movements.

There seemed to be no leader, the swaying starting one time in one part of the colony or even in several parts at once, and again in

[5] Published by permission of the director, U. S. Geological Survey.

some other part. Invariably, however, all would join in.

This habit was first observed by me several years ago, just how long I do not remember. It is associated with my earliest recollections of the insect. I have made more or less careful observation of it and taken notes several times, the first time in 1912. I do not think that I ever saw a colony that did not have the habit and I have had them in the laboratory every summer for several years. Observations of the habit may be made on colonies confined in the breeding cage or on those in the natural conditions. There seems to be no difference.

There is no doubt in my mind that this habit is an excellent example of synchronous rhythmic motion, not occasional or accidental, but habitual with the species. It may be well added to Mr. Craig's single, more or less doubtful, example, that of the chirping of crickets.

L. M. Peairs

Entomological Laboratory,
West Virginia University

THE POPULAR NAMES OF NORTH AMERICAN PLANTS

An article under this title in Science for February 2, by J. Adams, opens a question which has interested the present writer partly for the same reasons as there given, and he has passed through various stages of mental attitude toward it.

A notable fact is that common names when once established are apparently more stable than the scientific names. The names of birds furnish a good example of this, very few common names having been changed in the last fifteen years while a fourth or more of the scientific names have been changed, and some of them two or three times. However, the number of species of seed plants is about ten times as great as that of birds.

This very stability indicates difficulty in establishing common names where none exist. Names are a result of necessary "handles," and the greater part of those species which have not received them are not regarded frequently enough to establish names. The essential qualities of a name would seem to be significance and simplicity. The use of qualifying adjectives should be avoided as far as possible. The writer is not certain that a species must bear the same name in different regions, or that different species may not have the same one inasmuch as a name which is appropriate in one place may not be in another, and similar species often occupy similar places in different regions. The writer places much value on local lists, keys, etc., including a single state or natural area. This restricts the number of species involved and simplifies identification.

The surest way to acquaint the general public with the names of plants is through illustrations. Is it not possible to have a cooperative system by which different states would be responsible for certain portions and thus distribute the cost of production as widely as possible? This would eliminate the duplication now current from the publication of similar material in different places and permit the use of first-class illustrations of uniform quality, as well as help to unify the names.

O. A. Stevens

Agricultural College, N. D.

FAUNAL CONDITIONS IN SOUTH GEORGIA ISLANDS

During a recent visit to the islands of South Georgia (latitude 54° south) a very curious faunal condition was noted, and as this is, perhaps, of biological interest, it may be well to state briefly the facts of the case.

South Georgia lies in the sub-Antarctic region a few hundred miles to the east of Cape Horn. The season is open for about three months, but quite rigorous the remainder of the year. The principal vegetation is tussock grass, and this at one time supported many rabbits and perhaps a few other species of mammals. A few decades ago, the whaling industry was started with South Georgia as a base of operations. To-day there are nine whaling stations on the large island, and in a good season of three or four months, several thousand whales are handled. The carcasses are allowed to drift along the beach, as soon as the outer coating of blubber has been removed.

As a result of this, there are several miles of these huge decaying masses around the various stations.

Until about thirty years ago, there were no rats on the islands. At that time a sealing vessel allowed a few rats to go ashore, and the result to-day is appalling in its enormity.

The conditions have been ideal for these rats—with their nests in the tangled bunches of tussock and peat, and with a constant supply of meat in all stages of decomposition and cold storage close at hand!

There are literally millions of these rodents working away at the carcasses and swarming along the well-traveled trail which they have made on the mountain slopes. Even when the winter snows cover the place, operations in this rat haven are not stopped.

It was stated at one of the whaling stations that the rats have devastated the few small animals living on the island, and, indeed, are a menace to the health and safety of the place.

It would be interesting to know what characteristics the rat would develop after a few years of such a specialized habitat.

I. A. LUKE

SCIENTIFIC BOOKS

Les Sciences Biologiques Appliquées à l'Agriculture et la Lutte Contre les Ennemis des Plantes aux États-Unis. By DR. PAUL MARCHAL. Extrait des Annales des Épiphyties Tome Troisième. Paris, Librairie Lhomme. 1916. Pp. 30–390.

It does not seem like four years since Dr. Marchal visited this country and traveled from east to west and north to south, visiting the field laboratories of the Bureau of Entomology and educational institutions, yet actually that trip was taken in the summer of 1913. His book, under the title (translated) "Biological Sciences Applied to Agriculture and the Struggle against the Enemies of Plants in the United States," was received in this country in November last, its publication having been delayed by the war, and it is even now printed only in a very small edition. It is a large royal octavo volume covering nearly four hundred pages, abundantly illustrated. Marchal has a remarkable mind. It is little less than marvelous that in two months and a half he should have grasped the whole field in so perfect a way as to be able to write a book which is especially illuminating to us who are in the middle of things and who can not get the perspective which he reached after he returned to France and collected and classified his notes and impressions. The larger part of the book is devoted to the Bureau of Entomology, pages 52 to 198 being given to this service. The rest of the Department of Agriculture is considered in the following 30 pages, and 20 more are given to the experiment stations, the state entomologists, the Horticultural Commission of California, and the forestry services of the different states. Then follow 40 pages on universities and agricultural colleges, especial space being given to Cornell University and the universities of Illinois, California, Stanford and Harvard. He is enthusiastic over the Association of Economic Entomologists. The remaining 100 pages of the book are devoted to chapters on insect carriers of disease, the methods employed in the struggle against the enemies of crops (this chapter being divided into cultural methods, biological methods and technical methods), the laws concerning the protection of plants, including the insecticide law, and a conclusion. In this conclusion, after praising in an unstinted way the establishments of this country and the work which has been done, he especially points out that, far from narrowing itself in applications of science, the United States holds a place of the first rank in creative science. He thinks that France has much to learn from America, although it would be a mistake in his country to create an organization imitating in all respects the Department of Agriculture at Washington. He shows that the economic and cultural conditions are quite different on the two continents and that certain questions which have prime importance here have only a secondary interest in France. He is inclined to think that the United States Department of Agriculture is rather over organized, and thinks that the future will bring about a

simplification of its constituent elements. The main lesson that he learned by his journey is that France can no longer remain stationary in these matters and that it should make efforts to organize biology as applied to agriculture upon a large and solid basis, and he proceeds with practical suggestions in this direction. He praises the Federal Horticultural Board, the Federal Insecticide Board, and the Horticultural Commission of California, and thinks that all of these should be imitated in France. He especially points out the necessity for the introduction into France of such education as our young men get in applied biology in the agricultural colleges and universities like Cornell and Illinois. There is, he points out, in France at the present time no way of getting a scientific education in biological studies as applied to agriculture.

After pointing out some of the great examples of monetary saving in this country as the result of work in applied biology, he closes with the sentence, "These are great examples which it is well to recall, for they establish with the most complete evidence the fact that there is no other sure way than that of scientific organization of work to get full value from the national soil and to give back to agriculture the greatest possible part of the riches which are lost to it annually from pests."

L. O. Howard

CONCERNING THE HISTORY OF FINGER-PRINTS

Sir William J. Herschel published recently a brief pamphlet of 41 pages under the title "The Origin of Finger-Printing" (Oxford University Press, 1916). This is mainly an autobiographical sketch, giving in detail the story of how the author during the time of his useful service in India (1853–78) conceived the notion of finger-prints and elaborated this system, which was subsequently developed and placed on a truly scientific basis by Sir Francis Galton. We are indebted to Sir W. Herschel for his interesting document: it is always valuable when one who has played a prominent rôle in inaugurating a new movement presents us with a record of what he believes was his share in bringing about this innovation or invention. The inventor, however, will seldom be able to write impartially the history of his own invention; no one, in fact, whether statesman, artist, poet or scholar, while recording his own history, has the faculty (I should even say, the right) of clearly determining his own place in the long chain of historical development. This judgment must be left to the historian of the future. The principal purpose by which Sir W. Herschel was guided in writing his account is to demonstrate that he was the real "discoverer" of finger-prints in Bengal in 1858, entirely from his own resources, and to discredit all other claims to priority in this matter, especially those on the part of the Chinese. I regret that the author has failed to take notice of the "History of the Finger-Print System" published by me in the Smithsonian Report for 1912 (pp. 631–652, Washington, 1913). Not only are Sir W. Herschel's great merits and his share in the history of the invention, if invention it may be called, duly acknowledged and objectively expounded there, but he would also have found there all the available evidence in favor of the Chinese, Japanese and Tibetans, all of whom applied ages ago with full consciousness the system of finger-prints for the purpose of identifying individuals. The few modern traces of evidence known to Sir W. Herschel are treated by him slightly, and he wonders that "a system so practically useful as this could have been known in the great lands of the East for generations past, without arresting the notice of western statesmen, merchants, travelers and students." The Mohammedan authors who visited China did not fail to describe this system. Rashid-eddin, the famous Persian historian, who wrote in 1303, reports as follows:

> When matters have passed the six boards of the Chinese, they are remitted to the Council of State, where they are discussed, and the decision is issued after being verified by the *khat angusht* or "finger-signature" of all who have a right to a voice in

the council. · This "finger-signature" indicates that the act, to which it is attached in attestation, has been discussed and definitively approved by those whose mark has thus been put upon it. It is usual in Cathay [China], when any contract is entered into, for the outline of the fingers of the parties to be traced upon the document. For experience shows that no two individuals have fingers precisely alike. The hand of the contracting party is set upon the back of the paper containing the deed, and lines are then traced round his fingers up to the knuckles, in order that if ever one of them should deny his obligation this tracing may be compared with his fingers and he may thus be convicted.[1]

Professor Henri Cordier of Paris, the editor of Yule's famous work, adds to this passage a footnote relative to the history of finger-prints, and commenting on the claim of Sir W. Herschel, tersely remarks:

Sir W. Herschel was entirely wrong; Mr. Faulds protested against the claim of Sir W. Herschel, and finally a Japanese gentlemen, Kumagusu Minakata, proved the case for the Japanese and the Chinese. None of these writers quoted the passage of Rashid-eddin which is a peremptory proof of the antiquity of the use of finger-prints by the Chinese.

Indeed it is, and the observation that no two individuals have finger-marks precisely alike is thoroughly Galtonian. There is the earlier testimony of the Arabic merchant Soleiman, who wrote in A.D. 851, and who states that in China creditor's bills were marked by the debtor with his middle finger and index united (see my History, p. 643). But we have more. E. Chavannes, in reviewing my article in the *T'oung Pao* (1913, p. 490), has pointed out three contracts of the T'ang period, dated A.D. 782 and 786 and discovered in Turkestan (two by Sir Aurel Stein), which were provided with the finger-marks of both parties, and contain at the end the typical formula:

The two parties have found this just and clear, and have affixed the impressions of their fingers as a distinctive mark.[2]

A clay seal for which no later date than the third century B.C. can be assumed, and which bears on its reverse a very deeply and clearly cut impression of the owner's thumb-mark, has been brought back by me from China, and is illustrated and described in the above paper. I have also shown how the system was developed in ancient China from magical beliefs in the power of bodily parts, the individual, as it were, sacrificing his finger in good faith of his promises; in its origin, the finger-print had a magical and ritualistic character.

Sir W. Herschel states that he fails to see the definite force of the word "identification" in the Chinese finger-print system. In his opinion, there must be two impressions at least, that will bear comparison, to constitute "identification." He thinks, of course, one-sidedly of the detection of criminals to which the process has been applied by us, but never in the East (for what reason, I have stated elsewhere). Most certainly, the idea underlying Chinese finger-prints was principally that of identification, as expressly stated by Rashid-eddin and all Chinese informants. If a doubt or litigation arose, all that was necessary was to repeat the finger impression of the contractor who had formerly signed the deed.

B. LAUFER

FIELD MUSEUM,
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[1] See H. Yule, "Cathay," new ed., Vol. III., p. 123, London, 1914, Hakluyt Society.

[2] See A. Stein, "Ancient Khotan," Vol. I., pp. 525–529, Oxford, 1907, where the three documents are published and translated by Chavannes.

SPECIAL ARTICLES

ON THE COLLOID CHEMISTRY OF FEHLING'S TEST

I

As familiarly known, when Fehling's solution is treated with a reducing substance, it is generally expected that a bright red precipitate will be obtained. Frequently, however, an orange or yellow precipitate is obtained and in certain instances nothing but a yellowish-green or bluish-green discoloration results. The attempts to account for these differences are, for the most part, chemical in nature; it is held that the red reaction represents a precipitate of cuprous oxide, the orange or yellow ones more doubtful suboxides or hydrated forms of the oxide, while the character of the greenish discolorations is left doubtful. It is often be-

lieved that these latter represent but questionable evidence for the presence of any true reducing substances, or if conceded to be positive evidence for such, it is held that the reducing substances can not be present in great amounts.

An investigation of this series of changes from a colloid-chemical point of view reveals the fact that these color changes are coincident, not with differences in the nature of the reduction products, but only with differences in the size attained by the particles of reduced substance. If the copper oxide particles are brought down in very fine (subcolloid or colloid) form, the greenish discolorations are produced; as the copper oxide particles grow in size they become yellow, then orange, and when very coarse they are red. The series shows, in other words, what has been observed by different colloid-chemical workers: that one and the same material may, in the colloid state, show different colors, the color order following Wolfgang Ostwald's color law, according to which the most highly dispersed particles of a given substance are likely to be yellow, turning, as the size of the particles increases, to orange or red, and finally to violet, blue or black.

As to which of these possible colors will be obtained from a Fehling's solution undergoing reduction depends upon the conditions surrounding the reduction, the greenish discolorations being obtained whenever the conditions are such as will keep the cuprous oxide, as produced, in its finely divided state; while the red will result when opposite conditions obtain.

Three factors are chiefly concerned in the process:

1. Contrary to the generally accepted notion, the presence of too much reducing substance (as too much dextrose) is more likely to yield a greenish result than the presence of too little. This is because with much reducing substance the reduction starts from many points at once, but with exhaustion of the available copper salt the process comes to a halt before the cuprous oxide particles have attained any great size.

2. Irrespective of the amount of reducing substance present, the greenish discoloration will be obtained whenever materials are present in the reaction mixture which tend to stabilize the cuprous oxide in its finely divided form. Such materials are of the group of the lyophilic (hydrophilic) colloids and whenever present, either because added experimentally to reaction mixtures prepared in the laboratory or brought in with the mixtures being tested for reducing bodies (like diabetic urine) they incline to stabilize the cuprous oxide when this is still in a finely divided state.

3. With certain reducing substances (like dextrose) such "protective" hydrophilic colloids may be produced in the course of the reactions incident to the Fehling's test itself. In the action of the alkali of Fehling's solution upon dextrose, for example, there are produced, from a chemical point of view, not only the various degradation products which are responsible for the reduction of the copper salt, but, from a colloid point of view, many of these are colloid in nature and so tend to inhibit a precipitation of the cuprous oxide in coarse form.

Consideration of these various facts not only renders intelligible many of the excellent empiric instructions which different chemists have long found useful when Fehling's test for the qualitative or quantitative determination of various reducing bodies is employed, but they indicate also what schemes should be followed if it is desired to get the copper oxide precipitated in its coarse red form.

To allow adequate time for the growth of the cuprous oxide particles, it is better to make reductions at low temperatures than at higher ones. A Fehling's test carried out at room temperature by mixing the Fehling's solution with the suspected material and setting this aside for twenty-four hours is therefore more likely to yield a red precipitate than if the test is made by boiling the two together in the ordinary way.

Care should also be taken not to use excessive quantities of the material containing the reducing bodies. This not only avoids the possibility of using more reducing substance than there is available copper salt that may be

reduced, but it minimizes the possibilities of adding excessive quantities of protective colloids which might stabilize the cuprous oxide in its finely divided form. Finally, in doubtful cases, a dilution of the reaction mixture is always to be tried. By this method there is avoided not only excessive concentration of the reducing body itself, but through adequate dilution, both those protective colloids which may be added from without, or those which may be formed in the reaction mixture itself are likely to be diluted to a point where their effect in stabilizing the cuprous oxide in its finely divided form is largely lost.

II

While working on the reduction of Fehling's solution by formaldehyde, we encountered a series of reactions which, while largely familiar to the physical chemists since Bredig's classical studies on the inorganic ferments, are somewhat new in their sum total; and since the reactions are strikingly like those observed in biological material, we have used them to elucidate the nature of such biological reactions for our students.

Formaldehyde reduces a Fehling's solution not only to the ordinary cuprous oxide, but to the metallic copper. The copper comes down in colloid form, but as this happens, a second reaction ensues in which the metallic copper acts upon the formaldehyde and decomposes it with the liberation of hydrogen. The liberation of hydrogen continues for hours, until either all the formaldehyde has been decomposed or all the copper salt has been reduced.

We use this reaction as a biological analogue illustrating the formation of an enzyme (the reduced copper) from a series of simple "dead" materials (alkali, salts, carbohydrate). From another point of view we may say that the formaldehyde poisons or acts as a toxin upon the Fehling's solution. Against this the reaction mixture produces an antitoxin (the metallic copper).

The reaction may also be used to illustrate the action of different enzymatic poisons. Potassium cyanide, for example, when added to the Fehling's solution will not only prevent its reduction by the formaldehyde but, added after the reduction has been initiated, will inhibit or stop further reduction and liberation of hydrogen.

As emphasized by Hoppe-Seyler, the production of nascent hydrogen is held to be essential in the chemistry of respiration. But depending upon whether this production of hydrogen in a biological oxidation mixture occurs in the presence or in the absence of oxygen, totally different effects (as an oxidation in the one case or a reduction in the other) may be brought about. The same is true of the chemistry of a Fehling's solution when reduced by formaldehyde.

If a substance like methylene blue or phenolsulphonephthalein is added to the reaction mixture, these dyes are left untouched or are deoxidized, depending upon whether the reaction mixture is kept in a flat dish exposed to oxygen or in a tall tube from which oxygen is largely excluded. In other words, the first dye behaves just as in the classical experiments of Paul Ehrlich upon tissue oxidations; the phenolsulphonephthalein acts as in the experiments of E. C. Kendall. Phenolsulphonephthalein suffers reduction in the body whenever oxygen is absent while it is left untouched when this is not the case.

A detailed account of these experiments has been sent to the *Kolloid-Zeitschrift* for publication.

MARTIN H. FISCHER,
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EICHBERG LABORATORY OF PHYSIOLOGY,
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March 13, 1917

THE OIL CONTENT OF COTTON SEED AN ACCURATE BASIS FOR COMMERCIAL STANDARDIZATION

As a result of four years' work by the author, three of which are shown in the table below, and based on more than 500 determinations in the cotton industry laboratory of the Georgia State College of Agriculture, it was found that the oil content of cotton seed is an inherent characteristic of the variety, and that the percentage of oil in any variety can be increased by selection with no corresponding loss of other desirable qualities. Al-

though there may be slight variations from year to year, depending upon the season, these environmental factors influence all varieties alike, and the seed of the varieties that were high in percentage of oil the first year have remained so during subsequent seasons. The seed of the same variety when grown on the sandy soil of the coastal plains produce uniformly less oil than when grown during the same season on the red clay soil of the Piedmont Plateau. This difference varies from 0.51 gallon to 2.3 gallons per ton of seed, depending upon the variety. In a general way the varieties with the highest proportion of meats to hulls produce the most oil; but there is no positive correlation between percentage of meats and the oil content, since the percentage of oil in the meats varies with the variety.

TABLE SHOWING AVERAGE RESULTS OBTAINED WITH AIR-DRY SEED OF TWENTY-ONE VARIETIES OF COTTON GROWN FOR THREE SUCCESSIVE YEARS ON THE COLLEGE DEMONSTRATION FIELD, AT ATHENS, GEORGIA

Name of Variety	Per Cent. Moisture	Per Cent. Hulls	Per Cent. Oil in Seed	Total Gallons per Ton	Available Gallons per Ton	Per Cent.[1] Nitrogen in Seed	Equivalent to Standard 6.18 Per Cent. Meal
Rexall	7.62	38.34	23.30	62.14	50.50	3.47	1,067
Hite's	7.99	40.44	22.55	60.14	48.90	3.38	1,030
Perfection	7.15	38.91	22.38	59.68	48.10	3.50	1,037
Cook's	7.01	41.17	21.94	58.50	47.40	3.34	1,013
Willet's Ideal	7.46	41.43	21.78	58.08	47.00	3.33	1,016
Poulnot	7.63	41.16	21.38	57.01	45.70	3.39	1,052
Brown's No. 3.	7.66	42.18	21.24	56.64	45.60	3.31	1,018
Livesey's	7.70	40.75	21.07	56.19	44.90	3.45	1,052
Texas Bur	6.80	41.33	20.93	55.82	44.70	3.42	1,038
Brown's No. 1.	7.93	41.85	20.89	55.70	44.40	3.37	1,057
College No. 1	8.78	43.25	20.63	55.01	44.30	3.27	994
Hooper's	6.81	41.75	20.76	55.36	44.20	3.39	1,046
William's	7.51	41.44	20.75	55.34	44.10	3.42	1,061
Culpepper's	8.50	42.90	20.40	54.40	43.60	3.32	1,016
Cleveland	8.20	42.90	20.37	54.32	43.30	3.32	1,032
Brown's No. 2.	7.79	43.32	20.24	53.98	43.10	3.30	1,019
Christopher	7.25	42.52	20.18	53.82	42.80	3.37	1,034
Bramblett's	6.60	42.56	20.11	53.62	42.50	3.38	1,047
Meadow's	7.51	42.40	20.05	53.46	42.50	3.40	1,032
Caldwell's	7.04	43.01	19.93	53.14	42.30	3.35	1,018
Lankford's	7.94	46.38	18.88	50.34	40.10	3.14	969
Average	7.56	41.94	20.94	55.84	44.76	3.36	1,030

[1] Nitrogen determinations made by department of agricultural chemistry.

The seed from cotton plants grown upon soil to which fertilizer high in nitrogen has been applied are uniformly higher in nitrogen than seed from plants of the same variety grown during the same season on soil not so liberally supplied with this element—the average difference being less than one half of one per cent. The amount of nitrogen found in the seed from different varieties is fairly constant. In the seed of one variety only, did this variation exceed twenty-three hundredths of one per cent.

The difference in the value of the cotton-seed meal and the hulls, produced by a ton of seed from the variety yielding the most oil and the one yielding the least amount of oil was only forty-four cents, and the increased amount of lint on the seed of the inferior variety more than offset this difference. Therefore, there is practically no difference in the value of cotton seed aside from oil content, and the greatest variation between different varieties of seed in this respect was found in the season of 1914, when the percentages were 23.69 and 17.38, respectively. The average variation for three years was four and forty-two one hundredths per cent., or eleven and eight tenths gallons of oil per ton of seed. Taking the average price of seed for the same three years and the average yield of oil in gallons per ton of seed, it will be found that the price paid for the oil they contained was 82½ cents per gallon. On this basis there is a difference in value of seed from the varieties of high and low oil content shown in the above table of $9.73 per ton.

By eliminating the inferior varieties, the quality of the seed could easily be improved, thereby increasing their average value $5.00 per ton, and the present annual crush of more than five million tons would represent a saving of twenty-five million dollars per annum. This elimination could easily be effected if the seed were purchased on the basis of their oil content, and these data show conclusively that this is the only accurate basis of commercial standardization.

Loy E. Rast

Georgia State College of Agriculture,
Athens, Ga.

DEDICATION EXERCISES AT THE BROOKLYN BOTANIC GARDEN

ON April 19–21 exercises were held in connection with the dedication of the completed laboratory building and plant houses of the Brooklyn Botanic Garden. The programs at the various sessions were as follows:

APRIL 19

Formal exercises for officials, Garden members and invited guests. Lecture Hall, Mr. Alfred T. White, chairman of the Botanic Garden Governing Committee, presiding.

Introductory Address, Mr. A. Augustus Healy, president of the Brooklyn Institute of Arts and Sciences.

Address for the City of New York, Hon. William A. Prendergast, comptroller.

The social, educational and scientific value of botanic gardens, Professor John Merle Coulter, University of Chicago.

Addresses for the borough of Brooklyn, Hon. Lewis H. Pounds, president of the borough; for the Department of Parks, Hon. Raymond V. Ingersoll, commissioner of Parks, Brooklyn; for the Brooklyn Botanic Garden, Dr. C. Stuart Gager, director of the Garden.

10 P.M.

Reception by the trustees and woman's auxiliary, inspection of building and view of exhibit on genetics, arranged in cooperation with the Cold Spring Harbor Station for Experimental Evolution of the Carnegie Institution of Washington.

FRIDAY, APRIL 20

Dr. R. A. Harper, Torrey professor of botany, Columbia University, presiding.

A vegetative reversion in Portulacca, A. F. Blakeslee and B. T. Avery, Station for Experimental Evolution, Carnegie Institution.

Intercourses between self-sterile plants, E. M. East, Bussey Institution of Harvard University.

Evolution by hybridization, E. C. Jeffrey, Harvard University.

Binary fission and surface tension in the development of the Volvox colony, R. A. Harper, Columbia University.

The nucleus as a center of oxidation, W. J. V. Osterhout, Harvard University.

Modern applications of botany, Melville T. Cook, Rutgers College.

Mycelium of certain species of Gymnosporangium, B. O. Dodge, Columbia University.

Pathological problems in the distribution of perishable plant products, C. L. Shear, Bureau of Plant Industry, U. S. Department of Agriculture.

Some botanical problems which paleobotany has helped to solve. (Read by title.) Arthur Hollick, Staten Island Association of Arts and Sciences.

The ancient oaks of America. (Read by title.) William Trelease, University of Illinois.

Further notes on the structural dimorphism of sexual and tetrasporic plants in the genus Galaxaura, Marshall A. Howe, New York Botanical Garden.

A quantitative study of Raunkiaer's growth-forms as illustrated by the 400 commonest species of Long Island, N. Y. (Read by title.) Norman Taylor, Brooklyn Botanic Garden.

2 P.M.

Dr. N. L. Britton, director-in-chief, New York Botanical Garden, presiding.

The relation of crown-gall to other overgrowths in plants, Erwin F. Smith, Bureau of Plant Industry, U. S. Department of Agriculture.

The Uredinales of Oregon, Herbert S. Jackson, Purdue University.

The importation of phytopathogenes, W. H. Rankin, Cornell University.

Physiological races of parasitic fungi, George M. Reed, University of Missouri.

The genus *Endogone*, George F. Atkinson, Cornell University.

A method of obtaining abundant sporulation in cultures of *Alternaria solani*, L. O. Kunkel, Bureau of Plant Industry, U. S. Department of Agriculture.

The vegetation of our new West Indian Islands, N. L. Britton, New York Botanical Garden.

Weather conditions and plant development, G. P. Burns, University of Vermont.

American heaths and pine heaths, John W. Harshberger, University of Pennsylvania.

Botanical training in the Agricultural College. (Read by title.) A. Vincent Osmun, Massachusetts Agricultural College.

A duplicated leaf-lobe factor in Bursa, George H. Shull, Princeton University.

Isolation as a factor in specific change, Edmund W. Sinnott, Connecticut Agricultural College.

Further studies on the interrelationship of morphological and physiological characters in seedlings of *Phaseolus*, J. Arthur Harris, Station for Experimental Evolution, Carnegie Institution.

Inheritance studies in Castor beans. (Read by title.) O. E. White, Brooklyn Botanic Garden.

POPULAR SCIENTIFIC PROGRAM

Mr. Alfred T. White, chairman of the Botanic Garden Governing Committee, presiding.

Photographing wild flowers for color illustrations, Dr. Homer D. House, State Botanist of New York.

Vacant lot gardening and children's gardens in Brooklyn, Miss Ellen Eddy Shaw, curator of Elementary Instruction, Brooklyn Botanic Garden.

Problems of conservation in New York state, Hon. George D. Pratt, commissioner of Conservation of New York State.

APRIL 21

Dr. H. M. Richards, Columbia University, presiding.

The synchronism of plant structures, John M. Macfarlane, University of Pennsylvania.

Contact stimulation, G. E. Stone, Massachusetts Agricultural College.

The respiratory ratio of cacti, H. M. Richards, Columbia University.

The absorption of calcium salts by squash seed-

lings. (Read by title.) R. H. True, Bureau of Plant Industry, U. S. Department of Agriculture.

Duplication and cohesion in the main axis in chicory, A. B. Stout, New York Botanical Garden.

The sequence of life in peat bogs. (Read by title.) W. W. Rowlee, Cornell University.

Some observations on the sexuality of *Spirogyra*, H. H. York, Brown University.

The problem of the imported plant disease as illustrated by the White Pine Blister Rust. (Read by title.) Haven Metcalf, Bureau of Plant Industry, U. S. Department of Agriculture.

Outline of the history of the science of phytopathology, H. H. Whetzel, Cornell University.

Tubers within tubers of *Solanum tuberosum*, F. C. Stewart, New York Agricultural Experiment Station.

The rosy-spored Agarics of North America, W. A. Murrill, New York Botanical Garden.

Some botanical-pharmacognostical investigations, Henry Kraemer, Philadelphia College of Pharmacy.

The cytological structure of *Botryorhiza Hippocrateae*. (Read by title.) E. W. Olive, Brooklyn Botanic Garden.

APRIL 21

Conference to consider Vacant Lot Gardening and how the Botanic Garden may become Most Helpful to Teachers

Dr. C. A. King, Brooklyn Institute of Arts and Sciences and Erasmus Hall High School, presiding.

Welcome, Dr. C. Stuart Gager, director of the Brooklyn Botanic Garden.

The possibilities of vacant lot gardening in Brooklyn, Mr. H. F. Button, professor in the New York State School of Agriculture on Long Island.

How may the Botanic Garden cooperate with local schools? Dr. Ralph C. Benedict, Bushwick High School; Miss Beatrice King, Public School No. 25; Miss Johanna Becker, Public School No. 36; Dr. Frederic Luqueer, Public School No. 152; Miss Margaret Kane, Public School No. 98; Mr. James O'Donnell, Public School No. 43; Mrs. Alice Ritter, Public School No. 89.

Opportunities offered by the Botanic Garden, Dr. E. W. Olive, curator of Public Instruction.

What the Botanic Garden is doing for Brooklyn boys and girls. (With brief statements by ten boys and girls.) Miss Ellen Eddy Shaw, curator of elementary instruction; Miss Jean Cross, assistant curator of elementary instruction.

Tea was served at 4:30 P.M. by the Woman's Auxiliary of the Botanic Garden.

THE STANFORD MEETING OF THE PACIFIC DIVISION OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

The second annual meeting of the Pacific Division of the American Association for the Advancement of Science was held at Leland Stanford Junior University, California, between the dates, April 5 to 7, 1917. The headquarters of the Division were maintained in the rotunda of David Starr Jordan Hall, and the sessions of the several societies participating in the meeting were held in lecture rooms of the departments to which the societies were closely related.

Three general sessions of the division were held, the first of which was a symposium on the afternoon of Thursday, April 5, Dr. J. C. Branner, president of the Pacific Division, presiding. This symposium had been prepared by Dr. D. T. MacDougal, director of the Desert Laboratory of the Carnegie Institution of Washington, Tucson, upon the subject, "Coordination and Cooperation in Research and in Applications of Science." Four addresses were presented as follows:

"Science, and an Organized Civilization," by Wm. E. Ritter, director, Scripps Institution for Biological Research, La Jolla, California.

"The National Research Council as an Agency of Cooperation," by Arthur A. Noyes, director of Chemical Research, Throop College of Technology, Pasadena, California.

"Plans for Cooperation in Research among the Scientific Societies of the Pacific Coast," by J. C. Merriam, professor of paleontology, University of California, Berkeley.

"The Applications of Science," by William F. Durand, professor of mechanical engineering, Stanford University, California.

On the evening of Thursday, April 5, a general session was held in the assembly hall of the Outer Quadrangle, Dr. J. C. Branner, president of the division, presiding. At this session, President R. L. Wilbur welcomed the association on the part of the university, and Dr. James A. B. Scherer, president of Throop College of Technology, responded. In this response President Scherer extended the invitation of Throop College of Technology and other institutions of southern California to the Pacific Division of the American Association to hold its 1918 meeting in Pasadena. The nominating committee presented its report, nominating the following members to serve upon the Executive Committee for a term of three years each: Dr. W. W. Campbell, director of the Lick Observatory, Mount Hamilton; Dr. Wm. E. Ritter, director of the Scripps Institution for Biological Research, La Jolla, California, and Mr. C. E. Grunsky, president of the American Engineering Corporation, San Francisco. This report was accepted and the secretary was instructed to cast the ballot for these names. Following the transaction of this business, Dr. J. C. Branner, the retiring president of the Pacific Division of the American Association, presented his presidential address upon the subject, "Some of

the Scientific Problems and Duties at Our Doors.'' This session was followed by an informal reception to the faculty of the university and to the visiting members of the association at the home of President and Mrs. R. L. Wilbur.

The third general session of the meeting was held on the evening of Friday, April 6, Dr. J. C. Branner, president of the Pacific Division, presiding. At this session the executive committee reported the choice of Pasadena as the place for the 1918 meeting of the division, in response to the invitation given by President Scherer, the time for the meeting to be determined later. The executive committee also reported the election of Dr. D. T. MacDougal, director of the Desert Laboratory, Carnegie Institution of Washington, Tucson, Arizona, as president of the Pacific Division for the ensuing year, and Dr. Barton W. Evermann, director of the Museum of the California Academy of Sciences, San Francisco, as vice-president of the division and chairman of the executive committee for a term of three years. Together with the president and vice-president of the division, the executive committee for the ensuing year includes the three members elected at the previous general session of this meeting, and four members whose terms of office had not yet expired, as follows:

W. W. Campbell, director, Lick Observatory, Mount Hamilton, California,
E. C. Franklin, professor of chemistry, Stanford University, California,
T. C. Frye, professor of botany, University of Washington, Seattle,
C. E. Grunsky, president, American Engineering Corporation, San Francisco,
Vernon L. Kellogg, professor of entomology, Stanford University, California,
E. P. Lewis, professor of physics, University of California, Berkeley,
Wm. E. Ritter, director, Scripps Institution for Biological Research, La Jolla, California.

The following resolution introduced from the Pacific Coast Research Committee was unanimously adopted:

Since experimentation upon animals is indispensable to progress in the biological sciences, for the conquest of disease and for the relief of human suffering,

Be it resolved, That the Pacific Division of the American Association for the Advancement of Science hereby heartily endorses the use, under proper precautions, of unclaimed, impounded animals by the medical schools and universities of the state of California as contemplated in the Prendergast Bill (before the legislature of California).

Professor F. J. E. Woodbridge, of the department of philosophy of Columbia University, then presented a general address upon the subject, ''History and Evolution.''

At a meeting of the Pacific Coast Research Committee on Friday afternoon, April 6, together with representatives of the societies affiliated with the Pacific Division, a Pacific Coast Research Conference was organized. The purpose of this conference is expressed in the following resolution, which was introduced from the Pacific Coast Research Committee, and which was unanimously adopted:

''WHEREAS, It is the opinion of this committee that the important scientific problems before men of science to-day are those problems relating to preparation for war, which require scientific research,

''*Therefore, be it resolved,* That this committee, representing the scientific interests of the Pacific Division of the American Association for the Advancement of Science, offer to the State Council of Defense already formed in California, and to such other similar state or national organizations as may be organized, the full support and assistance of this committee in so far as it may be desired for the direction of research upon problems arising out of a condition of preparation for war.''

Among memorable occasions of the meeting were a series of luncheons given through the courtesy of the university in the Stanford Union on Thursday, Friday and Saturday, April 5 to 7, to which all members of the American Association and affiliated societies were invited. The opportunity for thus meeting in an informal social hour was greatly appreciated by every one.

Eleven societies held sessions on the occasion of this meeting. These were:

California Academy of Sciences,
Astronomical Society of the Pacific,
Pacific Section, American Mathematical Society,
American Physical Society,
Cordilleran Section, Geological Society of America,
Pacific Coast Branch, Paleontological Society,
California Section, American Chemical Society,
Seismological Society of America,
Le Conte Club,
Western Society of Naturalists,
Pacific Slope Branch, American Association of Economic Entomologists.

On the evening of Saturday, April 7, a dinner was held at the Hotel Sutter, San Francisco, under the auspices of the California Academy of Sciences, which was attended by about 85 members of the societies affiliated with the Pacific Division. Mr. C. E. Grunsky, president of the Academy, presided, and informal addresses were given by the following men: Dr. Wm. E. Ritter, Scripps Institution for Biological Research, La Jolla, California; Dr. D. T. MacDougal, Desert Botanical Laboratory, Carnegie Institution of Washington, Tucson; Professor Douglas H. Campbell, Leland Stanford Junior University, California, and J. C. Merriam, University of California, Berkeley.

On the same evening a dinner was held by the American Physical Society at the Stanford Union, Stanford University, and by members of the American Psychological Association at the Hotel Stewart, San Francisco.

On Saturday, April 7, an automobile excursion was conducted under the auspices of the Western Society of Naturalists, into the Coast Range foothills near Stanford University, which was attended by over forty biologists. Luncheon was provided by courtesy of the university at the recently completed field laboratory of the Department of Zoology.

Altogether twenty-two sessions were held during this meeting and over 130 papers were presented. The total registered attendance, in addition to a large local attendance from Stanford University and the vicinity, included 173 members of the association and of affiliated societies from other parts of the state and coast.

Albert L. Barrows,
Secretary

SOCIETIES AND ACADEMIES

ANTHROPOLOGICAL SOCIETY OF WASHINGTON

At the 510th meeting of the society, held at the New National Museum, Dr. Leo J. Frachtenberg, of the Bureau of American Ethnology, Smithsonian Institution, Washington, D. C., presented a paper on "The Religious Ideas of the Northwest Coast Indians."

Dr. Frachtenberg stated that four important features of the religious ideas noted among the tribes of this region are (1) an intensive animism; (2) a belief in the powers of supernatural beings, as dwarfs and giants; (3) a belief in the existence of guardian spirits, and (4) a complete absence of the social phase of religion.

According to Dr. Frachtenberg many religious ideas are common to all the tribes of the northwest coast, yet the northern and southern portions of this area differ in cosmogony. The tribes in the extreme southern portion believe that the world was created out of a watery mist, the Transformer enlarging a small piece of land until it became large enough for habitation. The tribes of the northern portion are satisfied with a world whose origin is not explained, they hold, however, that the Transformer (Creator) first made men, and members of the faunal and floral kingdoms, and later revisited and improved his creation. In the south the Transformer and Trickster are separate individuals; in the north they are unified. In the south the Transformer creates all that is good while the Trickster is held responsible for the bad elements; in the north there is no such disassociation, both good and evil things being regarded as the work of the Transformer.

The northwest coast Indians believe that an individual comprises a body inhabited by two "souls" and a "ghost." In a slight illness the "outer soul" becomes separated from the body, in a serious illness the "inner soul" wanders to the "country of souls" but may be recalled by a shaman. When death occurs the "ghost" also leaves the body and the shaman has no further power.

No ritual or systematic form of supplication is found among these Indians, indeed it may be said that guardian spirits take the place of deities. Every man and woman possesses one or more guardian spirits, each of which has its special sphere of influence. The shamans receive their power from a multitude of such spirits and are both respected and feared. Large gifts are exacted by the shamans, many of whom are believed to possess occult powers of evil.

The 511th regular and 38th annual meeting of the society was held at the New National Museum on April 17. After approving the reports of the secretary, treasurer and auditing committee the society elected the following officers for the ensuing year: *President,* Mr. William H. Babcock; *Vice-president,* Mr. Francis LaFlesche; *Secretary,* Miss Frances Densmore; *Treasurer,* Mr. J. N. B. Hewitt; *Councillors,* Mr. E. T. Williams, Mr. Neil M. Judd, Dr. Truman Michelson, Mr. Felix Neumann and Dr. I. M. Casanowicz.

Tributes to members of the society deceased during the previous year were then read, memorials to General Ellis Spear, an active member, and Mr. S. M. Gronberger, an associate member, being presented by Mr. William H. Babcock and Mr. James Mooney. A memorial to Mr. J. D. McGuire, an honorary member, was presented by Dr. J. W. Fewkes; and tributes to Professor Johannes Ranke and Professor Gustave Schwalbe, of Germany, honorary members, and Sir Edward Burnett Tylor, a corresponding member of the society, were given by Dr. Aleš Hrdlička, Dr. John R. Swanton, Dr. Truman Michelson and Dr. Leo J. Frachtenberg.

The delivery of the address of the retiring president, Dr. John R. Swanton, on "Some Anthropological Misconceptions," was postponed to a special meeting of the society to be held on May 1 for that purpose.

Frances Densmore
Secretary

SCIENCE

ILLUSTRATED SUPPLEMENT

N.S., Vol. XLV FRIDAY, MAY 25, 1917 Number 1169

Saunders' Text-Books

Stiles' Human Physiology
Human Physiology. By PERCY GOLDTHWAIT STILES, Harvard University. 12mo of 405 pages, illustrated. $1.50 net.

Stiles' Nervous System
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SCIENCE

ILLUSTRATED SUPPLEMENT

N.S., Vol. XLV FRIDAY, MAY 25, 1917 Number 1169

THE NEBULÆ

Address of the Retiring President of the American Association for the Advancement of Science.[1]

BY W. W. CAMPBELL

Director of Lick Observatory, University of California

IT is characteristic of most investigations in pure science that the quest is for the origin and history of things, and for the understanding of what now is, rather than for what is going to occur. One does not wisely venture to predict the future until he has explained the past and accounted for the present. Paleontologists are fruitfully studying the extinct animal life of our planet; several departments of science are busy with the life of to-day; and little effort has yet been made to forecast the animal life of the future. Anthropologists and ethnologists have been concerned with the men and the races of men who have already lived; they are just beginning to think scientifically of the men and the races that are to come. Conditions are moderately different in the one science, astronomy, whose chief domain lies far outside the earth and far beyond our sun. Some of the planets in our solar system may be passing through stages of existence that the earth experienced long ago, and others of our planets may be approximate examples of what is in store for the earth. When we undertake the study of the sun we have the great advantage that millions of suns within our view are representing the stages of stellar life through which our sun is thought to have passed, and millions of others the stages through which our sun will pass in the future. If we seek to know the history of our sun we can not avail ourselves of progressive changes in the sun itself. Such changes are too slow; we think the sun has remained substantially unchanged for hundreds of thousands of years. The student of stellar evolution proceeds by arranging the stars in general in the supposed order of their effective ages, and he endeavors to place our star and our planet at the logical points in the series. In this way astronomers, not unanimously, but in the great majority, have arrived at the conclusion that our own sun is in effect one of the middle-aged stars, and that our earth is in effect a middle-aged planet; and they attempt seriously to predict the future histories of the two bodies.

It is not my purpose to conduct you over the long road of stellar evolution. I shall invite your attention chiefly to the parts which the nebulæ seem to play in the development of the stellar universe; and this will lead me to touch lightly upon the birth and infancy of the stars, and to neglect the periods of their youth, middle life and old age.

[1] Delivered in the American Museum of Natural History, New York City, December 26, 1916. Illustrated by lantern slides.

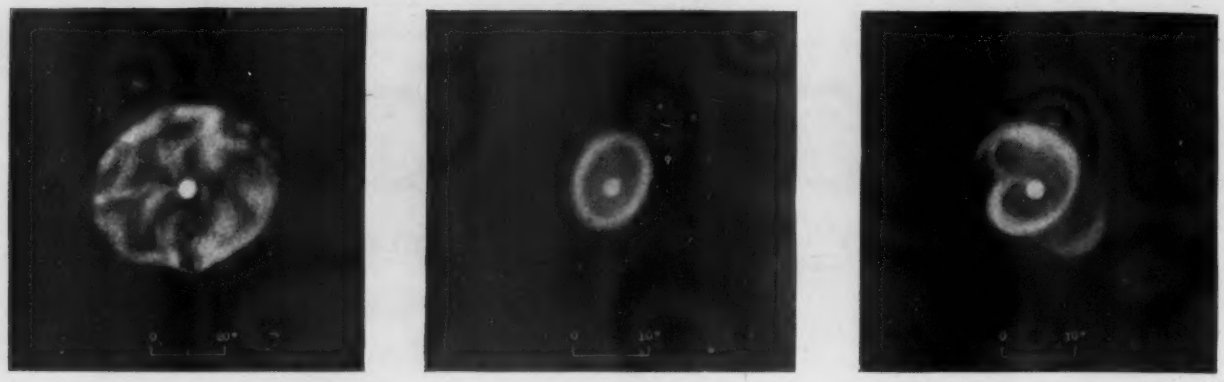


Fig. 1. (*a*) N.G.C. 1501. (*b*) N.G.C. 418. (*c*) N.G.C. 6543.
Planetary Nebulæ. Composite drawings by Curtis from his photographs with the Crossley Reflector of the Lick Observatory.

The classes of objects with which astronomers have to deal are very few. In our solar system we have the sun, the planets and their moons, the comets, the zodiacal light, and the meteors. To the best of our knowledge that exhausts the list. When we look beyond the solar system and out into the great stellar system we see only two classes of objects: the stars and the nebulæ; but there is an extremely great variety of each class, tens of millions of stars and tens of thousands of nebulæ, probably no two of either class exactly alike.

The serious study of the nebulæ began with Sir William Herschel in the 1780's. In less than two decades his famous sweepings of the sky had rewarded him with the finding of 2,500 nebulæ and star clusters. He did not separate them into a list of nebulæ and a list of clusters, as he was not clear about their relations to each other. When he observed certain of them with small telescopes and low magnifying power they looked like continuous structures, as if they were little clouds of luminous gases; but when some of the same objects were subjected to greater magnification they were resolved into star clusters. Here was the serious beginning of the hypothesis that all the nebulæ would be resolved into stars if only our telescopes were sufficiently powerful. Herschel was not satisfied with this view, and in 1791 he proposed the hypothesis that nebulæ evolve into stars. He thought that nebulæ of great size would condense very gradually, or break up, into smaller nebulæ; that the smaller ones would condense into nebulæ ever more and more regular in outline; and that these would eventually pass into the small, nearly symmetrical objects which he called planetary nebulæ, because in telescopes of low power they presented discs resembling the discs of our planets. He said the planetaries were the immediate forerunners of the stars, and that they would evolve into stars. Herschel actually classified a considerable number of the known nebulæ in accordance with this hypothesis. Speaking of a star surrounded by nebulosity, which is the condition existing in most planetary nebulæ (see Fig. 1), he said that the nebulous matter seemed "more fit to produce a star by its condensation than to depend upon the star for its existence."

Herschel's mind was profoundly philosophic, and his ideas about nebulæ attracted wide attention. They may easily have suggested Laplace's celebrated nebular hypothesis of the origin of our solar system, announced a few years later. Herschel thought of the birth of many stars from the nebulæ; Laplace's hypothesis ventured to describe in detail the process of the develop-

ment of one nebula into our sun, its planets and their moons.

It is necessary for the satisfactory presentation of our subject that we grasp the principal features of our stellar system, and we shall devote a few sentences to its description.

The universe of stars—our stellar system—is believed by astronomers to occupy a limited volume of space that is somewhat the shape of a very flat pocket watch; more strictly, a much flattened ellipsoid or spheroid. It is not intended to convey the impression that the boundaries of the stellar system are sharply defined, nor that the stars are uniformly distributed throughout the ellipsoid (see Figs. 2, 18 and others), but only that the stars are more or less irregularly distributed throughout a volume of space roughly ellipsoidal in form. The thinning out of stars near the confines of the system may be both gradual and irregular. The equatorial plane of the ellipsoid is coincident with the central plane of

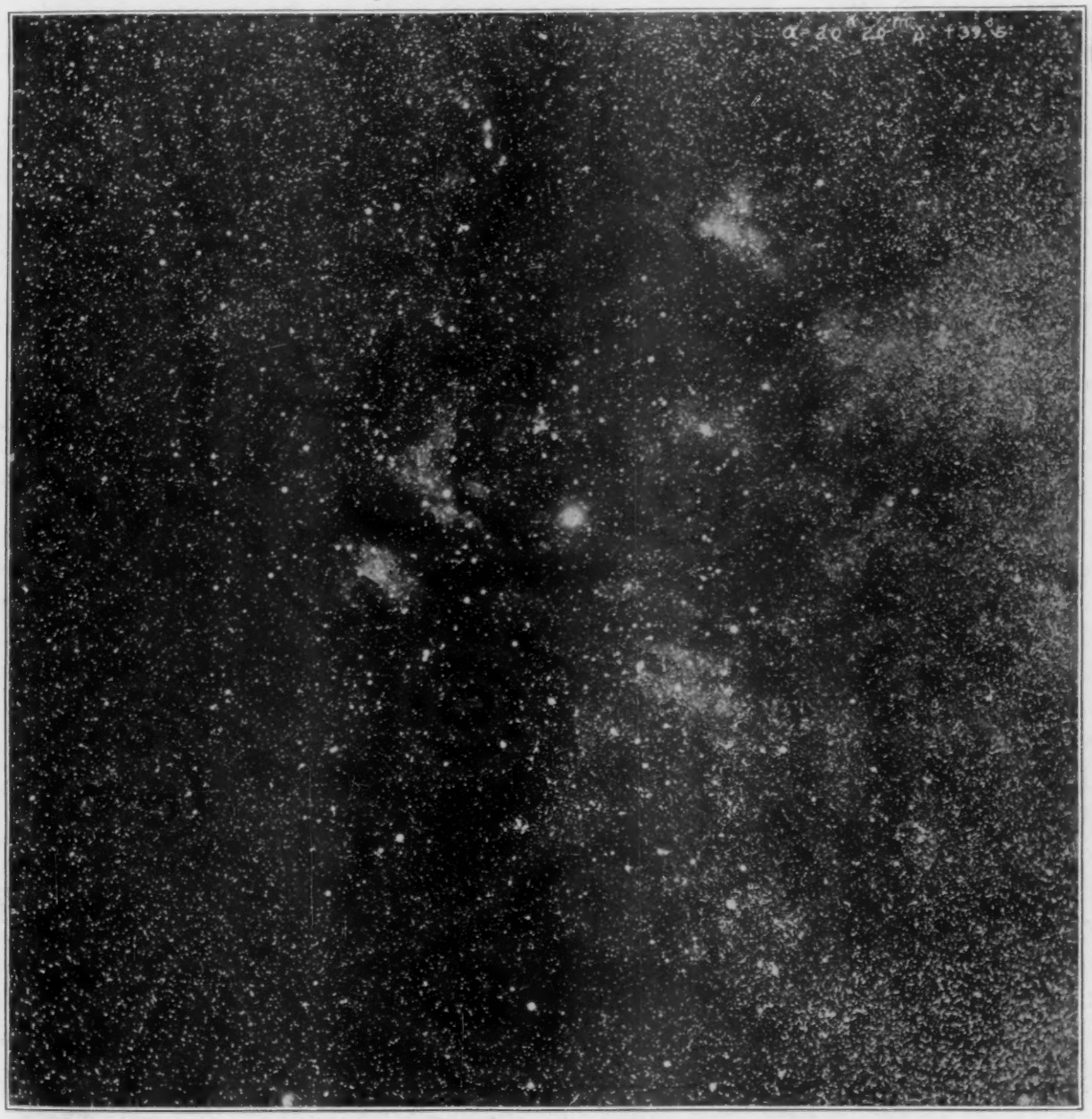


FIG. 2. Milky Way around the star Gamma Cygni, photographed by Barnard with the 10-inch Bruce telescope of the Yerkes Observatory.

the Milky Way. We see the Milky Way, or Galaxy, as a bright band encircling the sky because, looking toward the Galaxy, we are looking out through the greatest depth of stars. There remains considerable uncertainty as to the dimensions of the system, chiefly for two reasons: first, the stars near the surface of the ellipsoid are everywhere too far away to let us measure their distances; and, secondly, the system may be considerably larger than it seems because of possible obstruction of starlight in its passage through space. Newcomb has suggested that the shorter radius of the system, at right angles to the plane of the Galaxy, may be taken as of the order of three thousand light-years. The long radii, those in the plane of the Milky Way, may be at least ten times as great; that is, thirty thousand light-years, or more.

Our solar system is believed to be somewhere near the center of the stellar system: the counts of stars in all parts of the sky do not indicate that any one section of the Milky Way structure is appreciably closer to us, so to speak, than the other sections of it. It should be said that Easton's studies of the Galaxy place its probable center in the rich region of the constellation Cygnus.

These conceptions of the stellar universe and of the Milky Way agree in all important particulars with the ideas of Immanuel Kant published in the year 1755. However, it was the star counts by the two Herschels, father and son, which put this conception of the stellar system upon the basis of confidence. Sir William Herschel, using an eighteen-inch reflecting telescope in the northern hemisphere, and Sir John Herschel, using the same telescope in the southern hemisphere, counted the stars visible in the same eye-piece in 7,300 regions distributed rather uniformly over the entire sky. They found that the number of stars decreased rapidly as they passed from the central plane of the Galaxy toward the north and south poles of the Galaxy. Here is a table deduced by Struve from the Herschels' counts:

Galactic Latitude[2] Zones	Average Number of Stars Per Field 15′ in Diameter
+ 90° – + 75°	4.32
+ 75 – + 60	5.42
+ 60 – + 45	8.21
+ 45 – + 30	13.61
+ 30 – + 15	24.09
+ 15 – 0	53.43
0 – — 15	59.06
— 15 – — 30	26.29
— 30 – — 45	13.49
— 45 – — 60	9.08
— 60 – — 75	6.62
— 75 – — 90	6.05

The average number of stars in the Milky Way zone 30° wide, that is, between galactic latitudes + 15° and — 15°, visible in the eyepiece of the telescope, was fifty-six,[3] whereas in the regions surrounding the north and south galactic poles (latitudes between 75° and 90°) the average visible in the same eyepiece was but five.[3] The great condensation in the Milky Way is not fully evident from the table. The stars are much more numerous near the central line of the Milky Way than they are near its borders. The average number along the central line found by Sir William Herschel was 122. There is no reason to doubt that the pre-

[2] The galactic latitude of a star is its angular distance from the nearest point of the central line of the Galaxy, in the same way that the terrestrial latitude of a city is the city's angular distance from the nearest point of the earth's equator.

[3] A recent study of Mr. Franklin Adams's photographs of the sky, by Chapman and Melotte, shows a considerably smaller ratio than the 56:5 found by the Herschels. Seares has recently determined from Mount Wilson photographs that the number of stars per square degree along the central line of the Milky Way is more than twenty times as great as the number per square degree near the galactic poles; a result in remarkably close confirmation of the Herschels' counts. The source of the discordance between Chapman and Melotte's results and Seares's results remains unexplained.

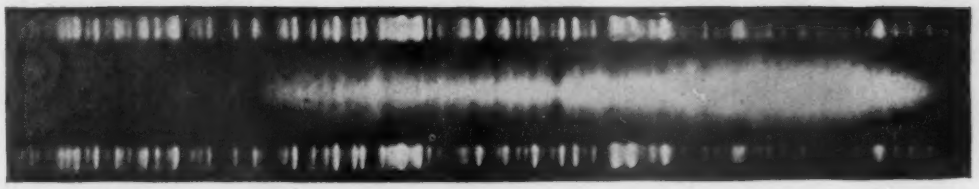


FIG. 3. The Spectrum of the Great Spiral Nebula in Andromeda, photographed by Slipher at the Lowell Observatory.

[The series of bright lines along the upper and lower margins are the reference spectrum. The nebular spectrum runs horizontally through the central area.]

ponderance of stars visible in the Milky Way is due to the greater extension of the stellar system in that direction than in the direction of the galactic poles.

Sir John Herschel, the son, extended the father's search for nebulæ to the southern sky, by observing at the Cape of Good Hope in the 1830's. He later charted all of the known nebulæ, both north and south, upon a sphere representing the entire sky, and found the surprising condition that the nebulæ in general avoid the Milky Way. Several decades earlier William Herschel had noticed within the Galaxy that the nebulæ are the more plentiful where the stars are scarce. When the stars in the eyepiece of his telescope would suddenly change from numerous to few he was accustomed to say to his recording assistant, "Get ready, nebulæ are coming." These general facts of stellar and nebular distribution, where stars are scarce nebulæ abound, and where stars abound nebulæ are scarce, led Herbert Spencer, among others, to emphasize the view that the evidence for a relationship of stars and nebulæ is overwhelmingly strong. This he called "the relationship of avoidance."

In the year 1864 occurred a great astronomical event. William Huggins pointed his spectroscope to a well-known planetary nebula in Draco (Fig. 1, *c*) and found that its visible spectrum consisted of three isolated bright lines (see Fig 32, N. G. C. 6543, the three lines at the right end of spectrum). This observation gave a death blow to the hypothesis then prevailing that all the nebulæ would prove to be clusters of stars if only our telescopes were powerful enough, or if the nebulæ were brought near enough to us. The spectroscope said very definitely and with finality: the Draco nebula is unresolvable; it is a mass of glowing gases. A cluster of stars can not give that type of spectrum. Other nebulæ were tested by Huggins's spectroscope. Some of these objects gave bright-line spectra, but the great majority had continuous spectra. Whether the latter were actually continuous or, as in the case of the sun and other middle-aged stars, the apparently continuous spectra of the nebulæ were really interrupted by hundreds and thousands of absorption lines, could not be decided because the nebular spectra were exceedingly faint. The eye could not have seen the absorption lines even if they were present. It is only in the last two decades, through the use of rapid photographic plates and of exposures a great many hours in length, that the existence of absorption lines in the continuous spectra of the nebulæ (see Fig. 3) has been proved for all of the nebulæ submitted to adequate test.

Lord Rosse's famous six-foot reflecting telescope marked an epoch in nebular research, in the year 1845, by showing that certain well-known nebulæ are of spiral structure—pretty certain evidence that they are in rapid rotation. Roberts's

photography of nebulæ in the '90's added to our knowledge of them, but the number of spirals known to exist was still not more than two or three dozen out of the approximately 10,000 objects listed in Dreyer's General Catalogues of nebulæ and clusters.

Fig. 4. Spiral Nebula Messier 81, photographed by Keeler with the Crossley Reflector of the Lick Observatory.

A great impetus was given to the study of the nebulæ when Keeler began to photograph them, in 1898, with the Crossley reflecting telescope of the Lick Observatory. His photographs, covering small areas in many different parts of the sky, recorded hundreds of nebulæ hitherto unseen. Using these small photographs as sample tests of nebular distribution, he estimated conservatively that his telescope could discover at least 120,000 nebulæ in the entire sky whenever he cared to undertake the work. Keeler's photographs were revolutionary in another sense: they led him to the capital discovery that the great majority of the nebulæ are spirals. Keeler's results have been abundantly confirmed by later observers: Perrine, Wolf, Fath, Curtis and others. Using the sixty-inch reflector of the Mount Wilson Solar Observatory, Fath photographed 139 small areas uniformly distributed over the northern three fifths of the sky, and he estimated from the number of the nebulæ recorded on his small plates that similar photographs completely covering the sky, 22,000 photographs, would

Fig. 5. Spiral Nebula Messier 51, photographed by Curtis with the Crossley Reflector of the Lick Observatory.

record about 162,000 nebulæ. Perrine, using the Crossley reflector, estimated the number discoverable as still greater. All the observers have found the faint nebulæ to present a variety of elliptic forms, such as we should expect if they are spirals

whose principal planes are distributed in direction at random. Many of them are approximately circles, as if they are spirals seen flatwise (Fig. 5); others appear as

FIG. 6. Spiral Nebula, edgewise, N.G.C. 4244, photographed by Keeler with the Crossley Reflector of the Lick Observatory.

spindles, or as spirals seen edgewise (Fig. 6); and the great majority have intermediate elliptic forms (Fig. 7). The plain inference is that the very faint nebulæ are for the most part, and perhaps almost entirely, spirals.

We have mentioned Sir John Herschel's charting of the nebulæ with reference to their distribution over the sky. Proctor charted all the nebulæ and star clusters known up to 1869, as in the illustration (Fig. 8). The positions of the nebulæ are indicated on the charts by the small dots. Their peculiar relationship to the Galaxy is apparent. The star clusters are plotted on the charts as crosses. It is clear that the clusters are found prevailingly in the galactic regions and in the two Magellanic Clouds (see Figs. 22 and 23), the Greater and the Lesser, which are about 20° from the south pole of the sky and are far to one side of the Galaxy. We should perhaps explain that the two Magellanic Clouds are great clusters of stars and nebulæ, covering many square degrees each, which have the same general appearance as many of the cloud forms of the Galaxy itself. We shall later find reason for believing that these Clouds are isolated stellar systems, separate from and independent of our stellar system.

It is the small star clusters, the clusters of rather widely separated stars, and the clusters of irregular form which show the strongest preference for the galactic regions; and there is no reason to doubt that all of such clusters belong to our system. The globular clusters, rich in stars and symmetrical in form, of which only 83 are known in the whole sky, likewise show a strong preference for the Milky Way, and it is probable that most of them, in fact nearly all of them, are within our stellar system; but the greatest of these clusters,

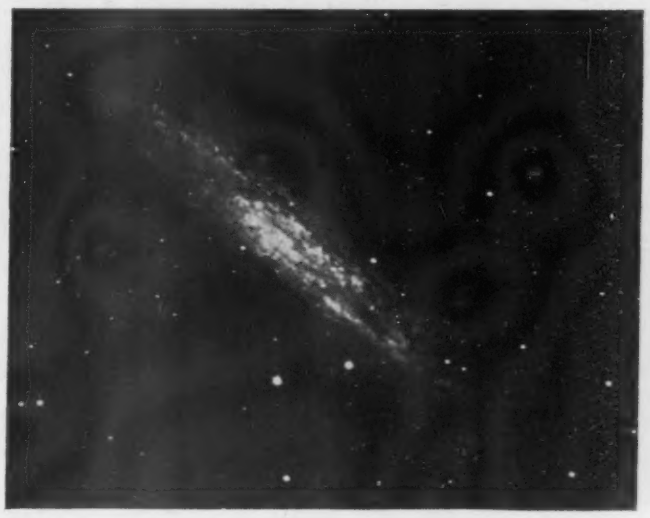
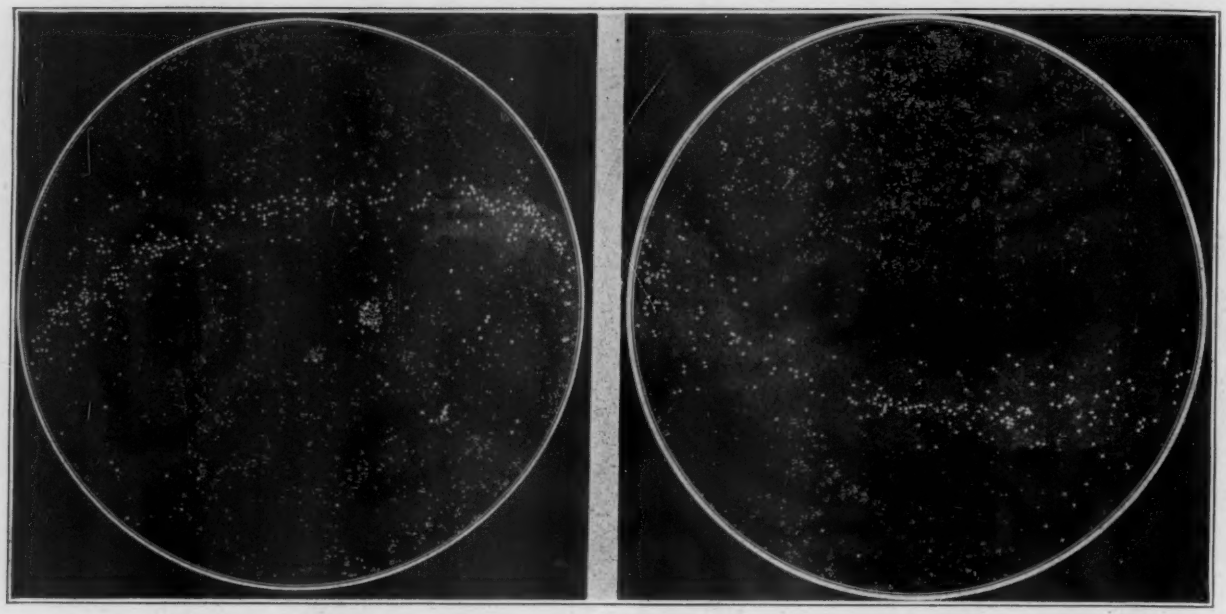


FIG. 7. Spiral Nebula N.G.C. 253, photographed by Keeler with the Crossley Reflector of the Lick Observatory.

such as the cluster in Hercules and two clusters even more prominent in the southern sky, are seen at considerable angular distances from the Milky Way structure.



Southern Hemisphere. Northern Hemisphere.

Fig. 8. Distribution of Nebulæ and Star Clusters according to Proctor. Nebulæ are marked by dots; clusters by crosses.

Fath's photographs, covering very small areas in the centers of 139 regions, recorded nebulæ hitherto undiscovered in the numbers set down in his chart, reproduced in Fig. 9. The curve drawn across the chart represents the central line of the Galaxy. The north pole of the Galaxy is at N, and the south pole is near S at the lower edge of the diagram. The distribution of the nebulæ is seen to be irregular and patchy, but the fact is indisputable that the faint nebulæ discovered with the most powerful photographic telescopes in the world, like the brighter nebulæ discovered visually by the Herschels and others, abhor the Milky Way. In the northern hemisphere, as

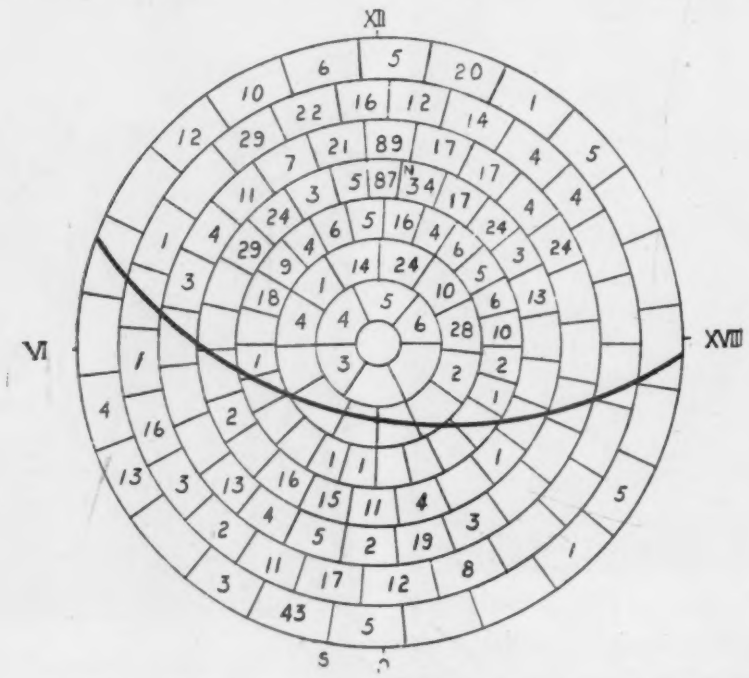


Fig. 9. Distribution of Faint Nebulæ discovered by Fath at Mount Wilson.

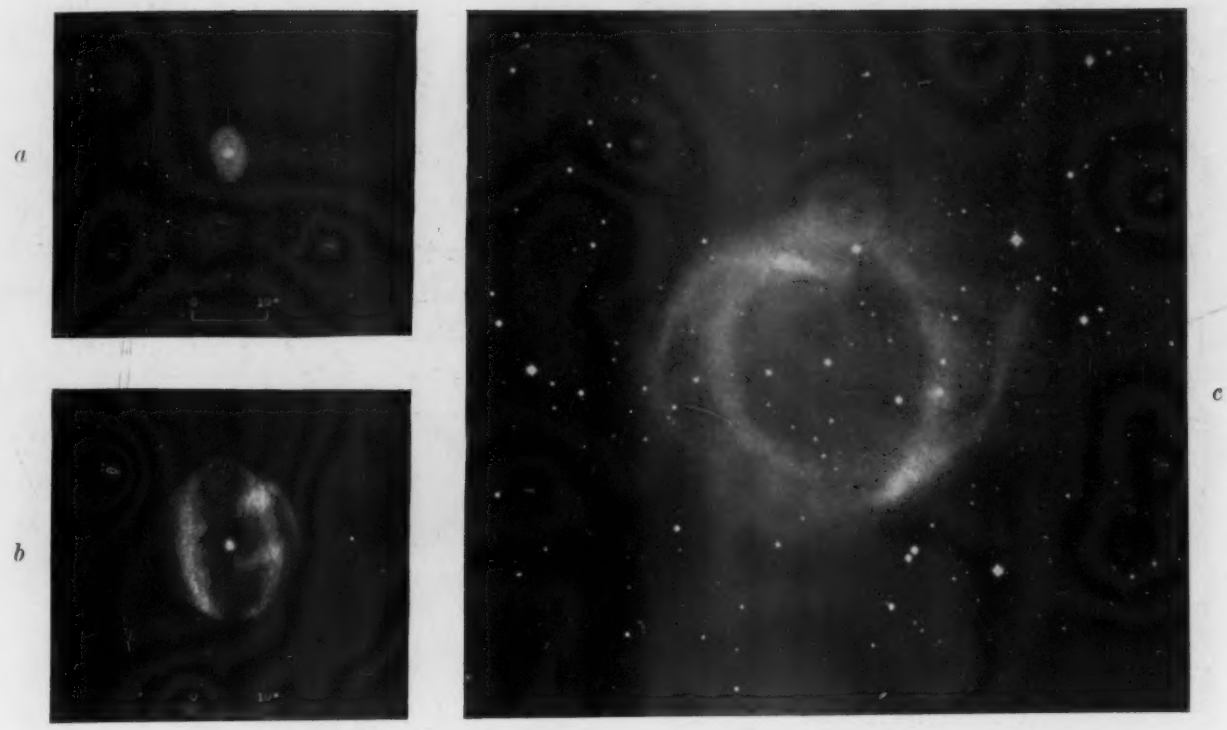


FIG. 10. Planetary Nebulæ. (*a*) and (*b*) are composite drawings from photographs, and (*c*) is a direct copy of a photograph, made by Curtis with the Crossley Reflector of the Lick Observatory.

(*a*) N.G.C.$_1$ 351. (*b*) N.G.C. 6818. (*c*) N.G.C. 7293.
1 inch = 8′.5.

Herschel and Proctor had established, they cluster more densely in the neighborhood of the pole of the Galaxy. In the southern hemisphere they show the same tendency, but not so strongly marked.[4] Two or three hundred of the brighter nebulæ have long been known to exist in and near the Milky Way, but faint nebulæ, such as those scores of thousands which Keeler showed are still awaiting discovery, are practically non-existent in the galactic region.

Let us examine more carefully the distribution of the nebulæ with reference to the Galaxy, and with reference to the physical conditions which seem to exist within them.

Out of approximately fifteen thousand nebulæ thus far discovered, fewer than 150 are planetaries. They exist in a variety of sizes, from a few that are only two or three seconds of arc up to others a quarter of a degree in diameter. The difference in size is due, at least in large part, as Curtis has recently made clear, to a difference in the distances of the bodies from us. A considerable number of them appear to be more and more condensed as we approach their centers, but the ring-form planetaries are the prevailing type (see Fig. 10). These rings of nebulosity are apparently not true rings, existing chiefly in two dimensions, but ellipsoidal shells of matter seen as rings in projection on the background of the sky. If they were true rings, we should see some of them as extremely elongated ellipses, and others ought to be long and slender as a result of seeing them edgewise. Those forms are wholly unknown. Now all of the planetaries give spectra consisting chiefly of isolated bright lines (see Fig. 32); that is, they are gaseous in constitution, and are

[4] It is not intended to convey the impression that the nebular distribution is merely a function of the galactic latitude; the observed nebulæ are more numerous in certain galactic longitudes than in others.

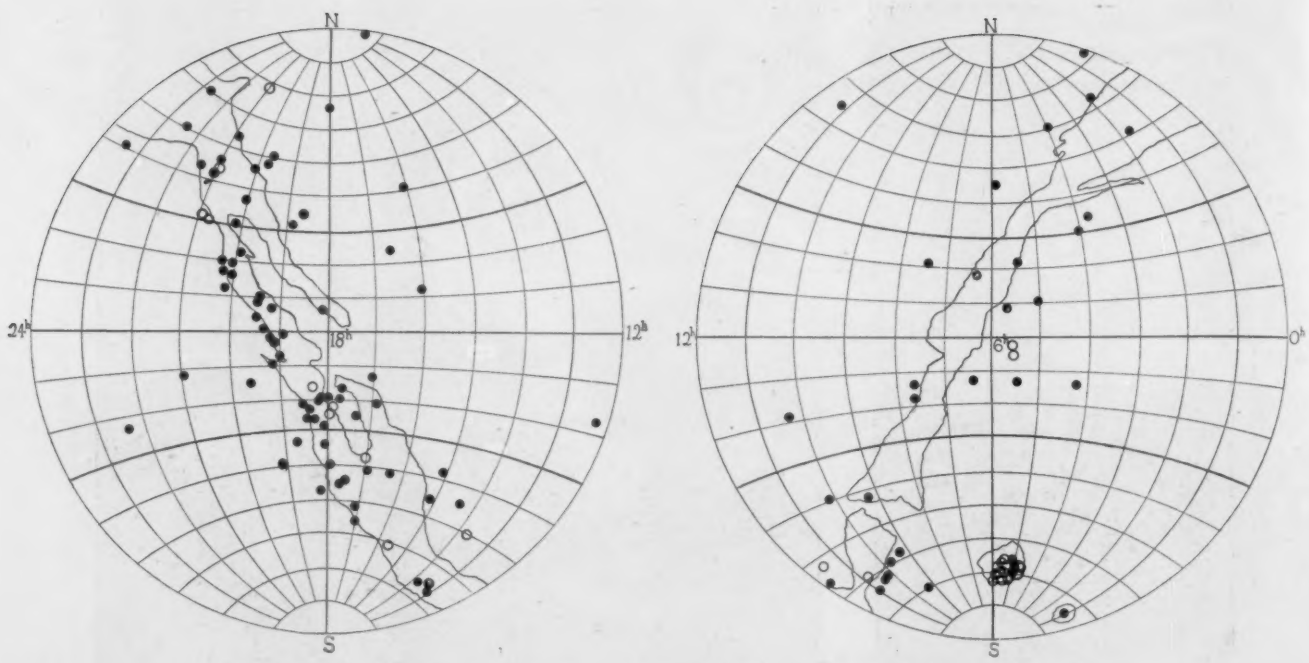


Fig. 11. Distribution of Planetary and Irregular Bright-line Nebulæ.
Right Ascen. 12^h to 24^h. Right Ascen. 0^h to 12^h.
● = Planetary nebulæ. ○ = Irregular bright-line nebulæ.
The irregular lines enclose the brighter galactic structure.
The positions of the Greater and Lesser Magellanic Clouds are shown above and to the right of the south pole of the right-hand chart.

shining by their own light. A very large proportion of them are in or adjacent to the structure of the Milky Way, or in the Magellanic Clouds (see Fig. 11). There are a few exceptions, but the exceptions almost certainly find their explanation in the relative nearness of these few to us, so that, being a little to one side of the central plane of the stellar system, they are seen in projection at some distance to one side or the other of the galactic structure.

The large irregular nebulæ whose spectra are known to consist of bright lines are charted as open circles. Such nebulæ at a considerable distance from the Galaxy are very scarce indeed.

The motions of approach and recession of the bright-line nebulæ have been observed with spectrographs at the Lick and D. O. Mills observatories. The large and formless bright-line nebulæ, such as the Trifid and Orion nebulæ, are almost at rest amongst the stars; their individual velocities are small, and the mean velocity of the group, with reference to our stellar system, is zero. These nebulæ, considered as a system, are not moving through the stellar system. They are in it and a part of it. Many of the planetary nebulæ (see Figs. 1 and 10) have high velocities, as individuals, but when we consider them collectively their motion with reference to the stellar system is in effect zero. They too are of our system.

There are in or not very far from the Milky Way many irregular nebulæ, of a great variety of sizes, whose types of spectra are for the most part unknown. They are intrinsically faint, and their investigation is a most promising problem of the immediate future. Two of these nebulæ, according to Slipher, have spectra identical with the brilliant stars which seem to be immersed in them; that is, continuous spectra, except as the absorption lines of helium and hydrogen are present in both

the nebular and the stellar spectra. These facts have led Slipher to favor the view that the two nebulæ are not shining by their own light, but by the reflected light of the brilliant stars in their midst. One of these is the nebula in which the Pleiades cluster is immersed (Fig. 13), and the other is around the bright star Rho Ophiuchi (Fig. 14). There are in the Milky Way many scores of nebulæ such as these, though for the most part fainter; but whether their spectra are of the bright-line type or reflected-light type, we do not know.

Our photographic telescopes are confirming William Herschel's observation that these large and formless nebulæ are in or are bordered by regions of sky showing fewer stars than abound in the surround-

FIG. 12. The Trifid Nebula, in Sagittarius, photographed by Keeler with the Crossley Reflector of the Lick Observatory.

W

S N

E

Fig. 13 The (inner) Pleiades Nebula, photographed by Keeler with the Crossley Reflector of the Lick Observatory. (By engraver's error the plate is reversed in one direction, as indicated by the letters W, N, E, S.)

ing regions. The bright stars in the Pleiades, those really belonging to the cluster, are numerous, but within the cluster as we see it, and in a considerable area of the adjacent sky, the faint stars are markedly scarcer than in the areas farther away. Barnard has found that the sky in the region around the Pleiades group is possessed of much nebulosity. It is a natural question, are the faint stars scarce because the nebulosity there existing has not yet condensed into stellar forms? This may be true in part, but we shall find much more probable the view that the faint stars are deficient in numbers because the nebular materials, at a certain distance away from us, are obstructing the light of the faint stars that are farther away from us than

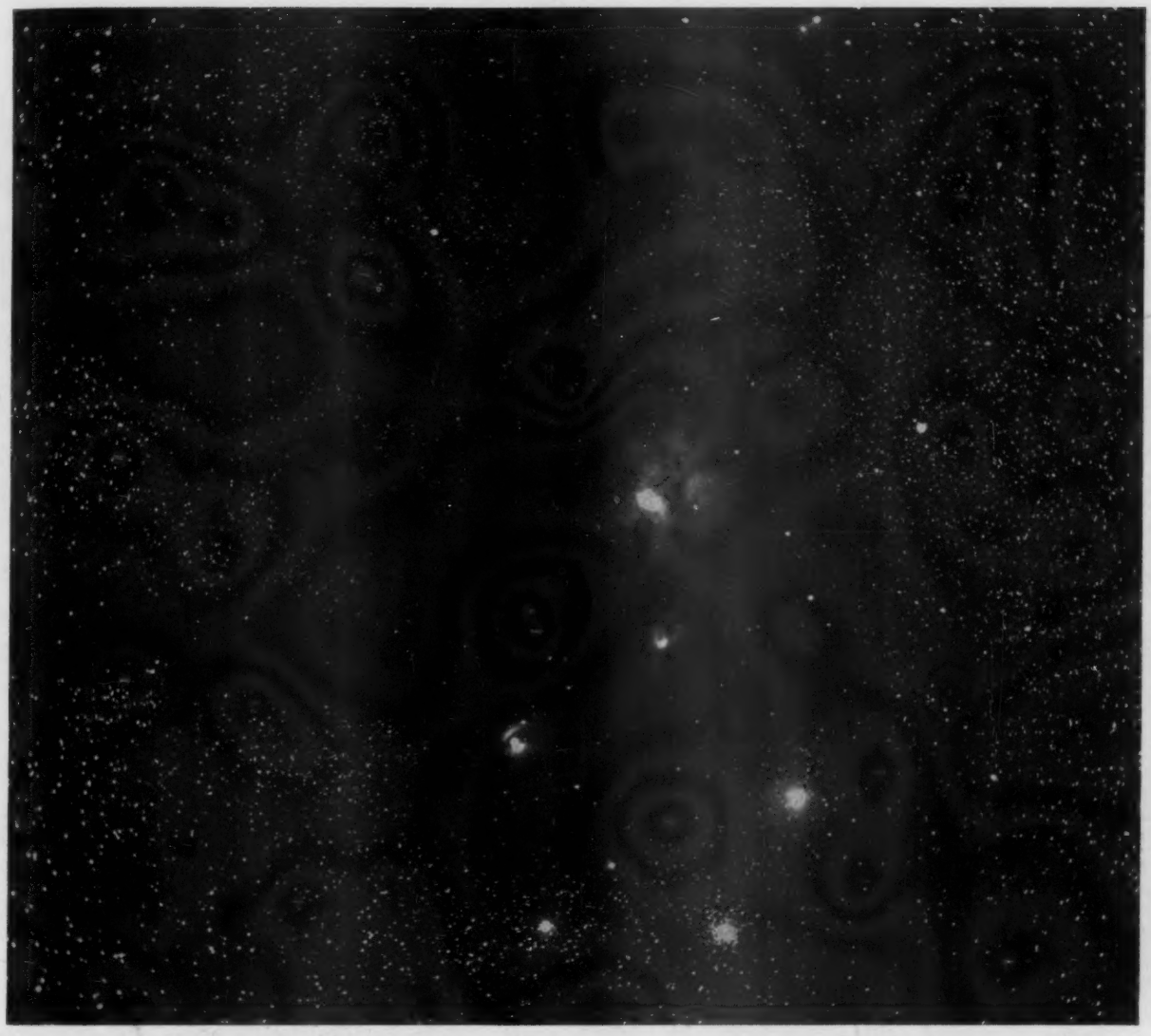


FIG. 14. The Milky Way around Rho Ophiuchi, photographed by Barnard with the 10-inch Bruce Telescope of the Yerkes Observatory.

the nebula is. A similar deficiency of faint stars exists within the great nebula of Orion, and likewise in the adjacent areas, where Mr. William H. Pickering has found a very large part of the constellation of Orion to be covered with faint nebulosity. We shall give illustrations of several regions (see Figs. 14, 15, 16) where this condition —the presence of nebulosity and the scarcity of faint stars—is so marked as to be at once apparent. There are so many regions in and near the Galaxy where these relationships exist that we can not doubt their significance. The faint stars are relatively scarce chiefly because the nebular materials cut off the light of the more distant stars. This explanation is reached by several lines of evidence, but we take time to present only one.

It is established by modern astronomy that the individual stars are in rapid motion. The speeds of the naked-eye stars average about sixteen miles per second. The distant fainter stars, so far as they have been observed, are also traveling rapidly. There is a tendency to favor certain directions of motion, and the stars in certain small groups are keeping company through space; but a large share of stellar motion is at random. There are stars traveling in all directions. We have not the direct evidence as to the motions of the

faint stars in the far distant outposts of the Galaxy, but we have no reason to suspect that their characteristic motions are unique. We can see no escape from the condition that all the stars are in motion. Under these circumstances we are unable to explain how within a great volume of

Fig. 15. Irregular Nebula N.G.C.$_2$ 5146, photographed by Curtis with the Crossley Reflector of the Lick Observatory.

(The circular halos around the brighter stars are unavoidable defects and are not real.)

space that is rich in stars there can be a smaller, but still enormous volume of space, nearly free of stars. Their random motions should distribute them more uniformly than we observe to be the case. Let us illustrate by the celebrated black holes, the so-called "coal sacks," in the constellation of Sagittarius (Fig. 17). In a region where the stars are especially plentiful are two small areas all but empty of visible stars. An enlargement of a photograph by Barnard, the preeminent student of this subject, shows the effect still better. How can such great "holes" through the stellar system be surrounded by a plenitude of stars moving more or less at random so as to give a high density of star distribution right up to the sharply defined edges of the holes, and yet leave the holes empty of stars? With the help of all astronomical experience we can not explain the phenomena by the absence of stars. I think we must assume, with Barnard and others, that the stars are actually there, and that they are invisible because invisible materials between us and the stars are absorbing or occulting the light which the stars are trying to send us. Much of the interesting structure in the Milky Way is probably due in a like manner to obstruction by materials lying between us and the great clouds of stars (see Fig. 18). It is characteristic of the galactic structure that where luminous nebulæ seem to reduce the numbers of faint stars visible, the reduction in numbers of stars extends also far out beyond the limits of visible nebulosity (see Figs. 14, 15 and 16), and we can scarcely resist the conclusion that invisible extensions of the luminous nebular fabric exist as obstructing agents.

There are many other lines of evidence in support of the hypothesis that invisible matter exists in abundance within the stellar system:

1. Newcomb and Kelvin, working independently and on the assumption that the motions of the stars are generated by gravitational attractions originating within the stellar system, were unable to account for the high observed velocities of stars, except on the hypothesis that the visible stars contain only a small fraction of the matter existing in the system; the greater part of the attracting material in the stellar sys-

FIG. 16. The North America Nebula, photographed by Barnard with the 10-inch Bruce Telescope of the Yerkes Observatory.

tem being non-luminous, or at least invisible.

2. There must be an enormous amount of comet material distributed throughout space. The astronomers discover only a negligibly small proportion of the comets which pass near the center of our solar system. May not comet materials exist also in abundance in the systems of the other stars?

3. Students of meteors have established that the separate little bodies which collide with the earth's atmosphere and are responsible for the so-called shooting stars are stupendous in numbers. It has been estimated that as many as twenty or thirty millions of such bodies collide with the earth every twenty-four hours. How incomparably and inconceivably greater must be the total number in our solar system. The power of these countless particles to obstruct the passage of light is not negligible. There may be as many such particles on the average around the other stars in our stellar system.

4. The so-called new stars, otherwise known as temporary stars, afford interesting evidence on this point. These are stars which suddenly flash out at points where previously no stars were known to exist; or, in a few cases, where a faint existing star has in a few days become immensely brighter. Twenty-nine such stars have been observed in the past three centuries, nine-

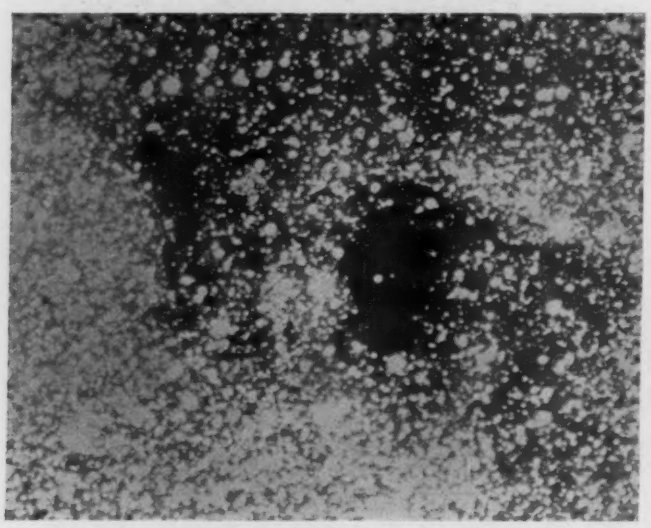


Fig. 17. The Dark Holes, or "Coal Sacks," in Sagittarius, photographed by Barnard with the 10-inch Bruce Telescope of the Yerkes Observatory.

teen of them since 1886 when the photographic dry plate was applied systematically to the mapping of the heavens, and fifteen of the nineteen are to the credit of the Harvard observers. This is an average of one new star in less than two years in the last three decades; and, as some of the fainter new stars undoubtedly come and go unseen, it is evident that they are by no means rare objects. Now all of the temporary stars except five appeared in the Milky Way, and four of the five exceptions are worthy of note. Two of the five appeared in well-known nebulæ; another was located close to the edge of a spiral nebula, and quite probably in a faint outlying part of it; a fourth was observed to have a nebulous halo about it; and the fifth was but meagerly and imperfectly observed. Keeping the story as short as possible, a temporary star is seemingly best explained on the theory that a dark or relatively dark star traveling rapidly through space has met with resistance, such as a great nebula or cloud of particles would afford. While passing through the cloud the star is in effect bombarded at high velocity by the resisting materials. The surface strata become heated, and the luminosity of the star increases rapidly. The new star of February, 1901, in Perseus afforded interesting testimony. Wolf at Heidelberg photographed in August an irregular nebulous object near the star. Ritchey's photograph of September showed extensive areas of nebulosity in all directions from the star. In October Perrine and Ritchey discovered that the nebular structure had apparently moved outward from the star (see Fig. 19). Going back to a March photograph, taken for a different purpose, Perrine found recorded upon it an irregular ring of nebulosity closely surrounding the star which was not visible on later photographs. The region seemed to be full of nebulosity not visible to us under normal conditions. The rushing of the dark star into and through this resisting medium made the star the brightest one in the northern sky for several days. The great wave of light going out from the star when at this maximum brightness traveled far enough in five weeks to fall upon non-luminous materials and made a ring of nebulosity visible by reflection. Continuing its progress, with a speed of 186,000 miles per second, the wave of light illuminated the material which Wolf photographed far away from the star in August, the material which Ritchey photographed still farther away in September, and the still more distant materials which Perrine and Ritchey photographed in October, November and in later months. We

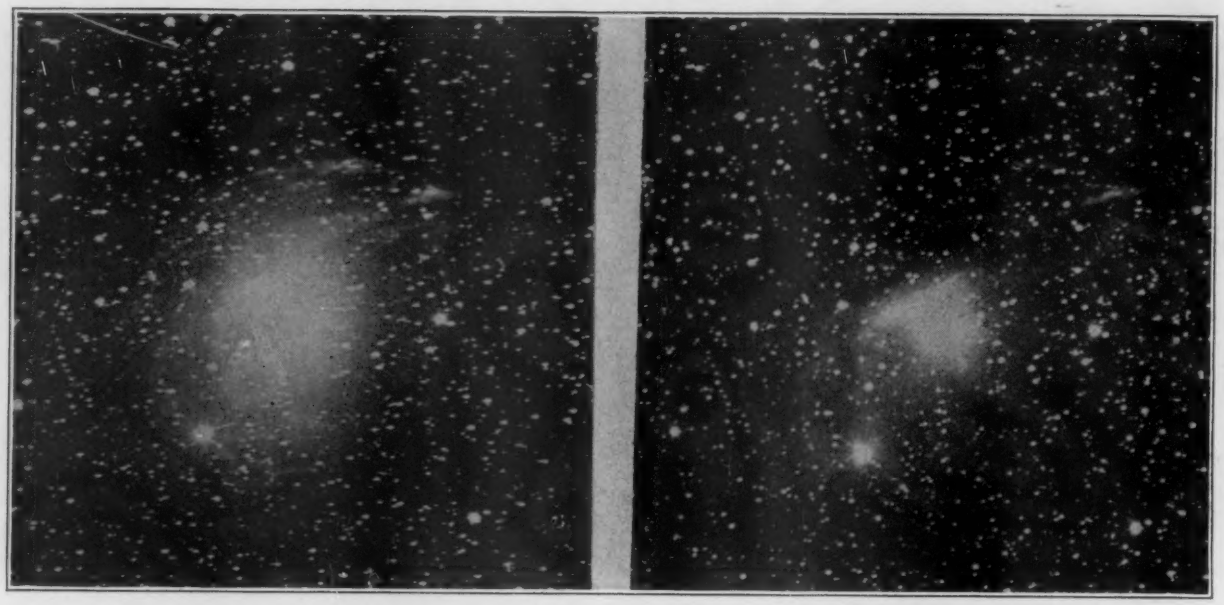
FIG. 18. The Milky Way in Ophiuchus showing apparent absorption or obstruction effects; photographed by Barnard with the 10-inch Bruce telescope of the Yerkes Observatory.

were able to see this material only as the very strong wave of light which left the star at maximum brightness made the material luminous in passing.

We can scarcely doubt, in view of all these facts, that there is a stupendous amount of obstructing material scattered throughout our stellar system. This may eventually be condensed into stars; but the point I wish to emphasize is that the material is there, and is evidently obstructing the passage of light. The efficiency of the obstructing material is no doubt the greater in the long dimensions of the system; in the direction of the Milky Way.

Let us now consider the nebulæ which are not in or near the Galaxy. The overwhelming majority of the stars are in the galactic zone of the sky. If we call this zone 30° wide, which makes it a shade over one fourth the entire sky, we may say that this fourth-area contains certainly three fourths of all the stars known to exist in our stellar system. The remaining three fourths of the sky do not show more than one fourth of all the stars. Of about 15,000 nebulæ recorded probably not over 300,[5] certainly

[5] It is not practicable to state the number more definitely. To illustrate the difficulty, we mention the fact that several small adjoining nebulæ re-



November 12 and 13, 1901. January 31 and February 2, 1902.

Fig. 19. Apparent movement of nebulous matter about Nova Persei. Photographed by Perrine with the Crossley Reflector of the Lick Observatory.

[The motion is best shown by the bright mass above and to the right of the center, in comparison with the surrounding stars.]

not over 400,[5] are found in the galactic zone. That is, not more than one fortieth or one fiftieth of the known nebulæ are in that one fourth of the sky which contains the Milky Way; and these possible 400 galactic nebulæ include nearly all of the planetary nebulæ, nearly all of the large gaseous nebulæ, nearly all of the regions where large absorbing or obstructing nebulæ are seen to be effective; in other words, as I have endeavored to make clear, nearly all of the nebulæ that are really within our stellar system. The other three quarters of the sky contain, on the contrary, nearly 15,000 recorded nebulæ. The nebulæ to the south of the galaxy have not been so well observed as those to the north, and we shall here consider the northern galactic hemisphere alone. The one quarter of the northern hemisphere immediately around the pole of the Galaxy contains three fourths of all the recorded nebulæ in the whole hemisphere, and the quarter of the hemisphere adjoining the central line of the Galaxy contains about one fiftieth of all the recorded nebulæ in the hemisphere. The density of nebular distribution in the Galaxy is only one fortieth that in the quarter-area farthest away from the Galaxy. A still more interesting fact concerning nebular distribution is this: *thousands of spiral nebulæ are known to exist, but not a single spiral nebula has been found within the galactic structure.* Some spirals have been found in regions adjoining the Galaxy, but they are relatively few. The spirals in particular abhor the Milky Way. As we said above, the very avoidance of the Milky Way seems at first sight to show that they are arranged with reference to it; that they hold some relation to it. Is this relationship real, or only apparent? Are the spiral nebulæ in or attached to our system, or are they outside of our system, at tremendous distances from us? This question is a live one in the astronomy of to-day. The old hypothesis that the unresolved nebulæ are

corded with a short exposure may be seen to be but parts of one great nebula when the exposure is longer.

other great universes of stars very far distant from our own universe of stars is receiving favorable consideration, as far as the spiral nebulæ are concerned. In fact, the related hypothesis that our own stellar system, if viewed from a stupendous distance, would be seen as a spiral nebula, has been seriously proposed and is receiving favorable consideration. There is much merit in the hypothesis that if an observer went very far away from our system, in the direction of one of the poles of the Galaxy, and looked back to our stellar system, he would see it fairly circular in outline, and that the cloud forms which we see in the galactic structure would to the distant observer resemble the ill-defined condensations so characteristic of the outer structure of spiral nebulæ (see Fig. 5). If the observer were at a very great distance outside of our system in the plane of Milky Way extended, we certainly think he would see our system as a greatly elongated ellipse resembling the many well-known spindle nebulæ which are interpreted as spirals seen edgewise (see Fig. 6).

Whether we regard the spirals as very large bodies at enormous distances, far outside and independent of our system, or as within our system and therefore comparatively small bodies close to us, we encounter apparent difficulties of interpretation. These proceed chiefly from their avoidance of the direction of the Milky Way. We are not content to think of this relationship of avoidance as a coincidence or accident of nature. If the spirals are far outside our system, we should expect to see a great many of them in the direction of the Milky Way, but beyond its structure.

We have seen reasons for believing, or at least strongly suspecting, that there is an immense amount of obstructing material in our system, and that this would be the most extensive and the most effective in the long dimensions of our system, and the least effective in the direction of the short axis of the system. If such obstructions are operating effectively upon the light of extremely faint and extremely distant nebulæ, they should produce something like the distribution which we actually observe to exist amongst the spirals.

FIG. 20. Hypothetical Cross section of our Stellar System, showing spaces *N* and *S* occupied by the spiral nebulæ if they are within the stellar system.

Let us suppose, on the other hand, that the spirals are in our system. Why do we not find them in the Milky Way structure? Why do they absolutely avoid that structure? Why do they congregate around the shorter axis of our stellar system? If they are within our system they must be distributed as to distance and direction somewhat as sketched in the conical volumes N and S in Fig. 20, which represents a cross-section

of the stellar system, with the solar system somewhere near its center. This is an assumed distribution which leads straight into difficulties and to some degree of absurdity. We should have to say that the spirals live close to the right of us and close to the left of us, but that they avoid getting between us and the Milky Way structure.

Slipher has measured the motions of approach and recession of more than a score of prominent spirals, and he finds they are moving with speeds surprisingly high, running up to 600 or 700 miles per second, with an average of roughly 250 miles per second. Now, if they are moving at random, which is the probable approximate truth, their average speed at right angles to the line of sight must be still higher, and their average speed in space would be of the order of 500 miles per second. There is no class of objects known to exist within our stellar system which have velocities at all approaching that scale.

Curtis has conducted an extensive investigation to determine whether and how much the principal spiral nebulæ have moved on the surface of the sky in the last fifteen years, on the basis of photographs taken at the beginning and at the end of that period. Lampland and van Maanen have similarly sought for evidences of change of position of three or four spirals. The indications of motion in all these cases are so slight as to leave us uncertain whether the motions of the brighter and larger spirals across the face of the sky in fifteen years have been sufficient for detection. Harmonizing this fact of their vanishingly small angular motions with Slipher's high speeds in miles per second, we conclude that they must be enormously distant, and therefore enormously large bodies.

With the spectrograph, Slipher has been able to measure the rotational speeds of two or three spirals, including the great spiral in Andromeda, and Pease has repeated and extended the experiment on one of them. The rotational speeds are also extremely rapid, as indeed one should expect from the tremendous inequalities in what we venture to call their equatorial and polar diameters. Assuming that Newton's law of gravitation controls their rotations, the probable masses are stupendous. Some of them seem to contain enough material to make tens of thousands, probably hundreds of thousands, and possibly millions, of stars comparable in mass with our own sun.

The spectra of only a few of the brighter spirals have thus far been investigated in any degree of adequacy, but they have the characteristics which we should expect to find if the spirals consist chiefly of multitudes of stars. I say chiefly, because in the spectra of some of them we find the bright-line spectrum of gaseous nebulæ superposed upon what we may call the stellar type of spectrum.

If we carried our spectrograph so far out into space that, looking back, our stellar system would be reduced down to the apparent size of the well-known spiral nebulæ, and we turned the instrument upon our condensed system, we should expect to see a spectrum very like the continuous and absorption-line spectra yielded by the spirals; and certain structures in our system, such as the region containing the Orion nebula, might well yield the bright nebular lines found in some parts of certain spirals. Curtis has recently examined the spectra of fifty of the brighter small nebulæ lying within 25° of the Galaxy which had not been subjected earlier to spectroscopic test. None of them showed bright lines; all appeared to be of the stellar or cluster type of spectrum. An extension of the survey to the pole of the Galaxy would probably have had similar results.

We are not able to resolve the spirals into stars, except as we seem to be ap-

FIG. 21. The Spiral Nebula, Messier 33, photographed by Keeler with the Crossley Reflector of the Lick Observatory.

proaching resolution in certain parts of one great spiral, Messier 33, in the constellation of Triangulum (Fig. 21). That one is probably relatively near us, but of that we are not sure. Some astronomers who have photographed the Magellanic clouds (see Figs. 22 and 23), in the far southern sky, say that these remarkable objects are spiral in structure. If so, they are spirals easily resolved into stars. Nevertheless, these clouds are enormously distant. Hertzsprung has estimated, from certain considerations, that the distance of the Lesser Cloud is of the order of 30,000 light-years. Wilson has measured the spectroscopic velocities of approach and recession of twelve nebulæ in the Greater Cloud, and has found that they are receding with speeds lying between 150 and 200 miles per second. The velocities of the twelve objects differ from each other as many miles per second as we should expect to find for twelve bright-line nebulæ selected at random in our galactic system, but the average for the twelve in the Cloud shows an abnormally high rate of recession. All of the known bright-line nebulæ in that great region of the sky are in the two Clouds. None is known to exist outside of the Clouds until we have gone far from them in the direction of the Milky Way (see Fig. 11). There are still other reasons for the unquestioned conviction

that these nebulæ are actually a part of the structure of the Clouds. It is difficult to avoid the conclusion that the observed speed of recession of the twelve nebulæ within the

Fig. 22. The Greater Magellanic Cloud, photographed by Bailey, at the Arequipa, Peru, station of the Harvard College Observatory.

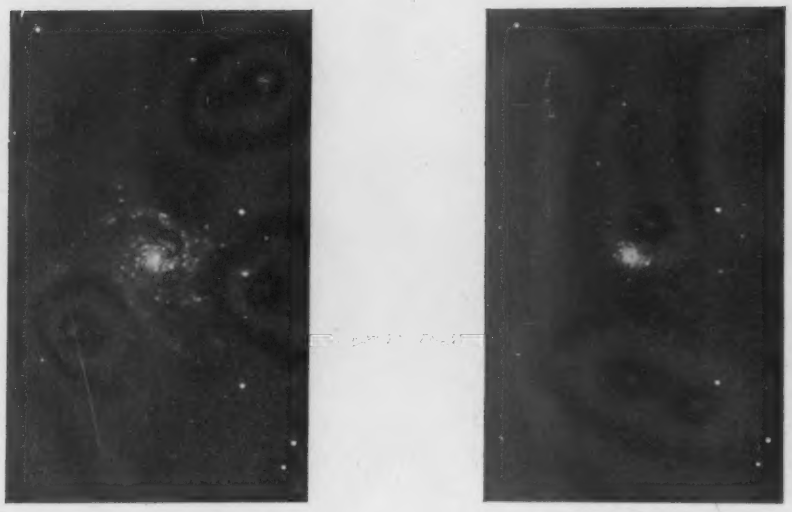
Greater Cloud, averaging 175 miles per second, is the approximate speed of recession of the Greater Cloud. Motions of this magnitude have not been observed for any objects known to be within our stellar system, except in the case of three or four individual small stars. We can not seriously doubt that the Magellanic Clouds are distinct from and independent of our great stellar system; and, if they are of spiral structure, they are spirals relatively near to us, as the distances of spirals go.

Seares has recently discovered an interesting peculiarity of spiral nebula, at least of the four or five thus far studied, by means of photographs of spirals, with exposures first on ordinary plates sensitive to the blue-violet rays, and secondly on isochromatic plates and through screens which transmit only the yellow-green rays. The results, illustrated in Fig. 24, show that the light from the outer arms of the spirals is richer in the blue and violet rays than is the light from the central nuclei. The significance of these facts is not yet clear.

We can not say that the problem of interpreting the spiral nebulæ has been solved. In fact, it is a fair statement that our positive knowledge as to the conditions existing within them is regretfully meager. *We are not certain how far away they are; we are not certain what they are.* However, the hypothesis that they are enormously distant bodies, that they are independent systems in different degrees of development, is the one which seems to be in best harmony with known facts. It should be said that this hypothesis is a very old one. Swedenborg speculated upon the idea that our stellar system is but one of a great number of systems. The serious consideration of the hypothesis, upon the basis of observed facts, may be said to date from the two Herschels. Following Keeler's epoch-making observations of nebulæ in 1898–1900, many astronomers have studied the subject.

We naturally ask why it is that certain globular star clusters are visible not far to one side or the other of the Milky Way, whereas the spirals there are faint and

Fig. 23. The Lesser Magellanic Cloud, photographed by Bailey, at the Arequipa, Peru, station of the Harvard College Observatory.



Seed 27, 20 min. Iso, 2 hours.

FIG. 24. The Spiral Nebula, Messier 99, photographed without and with absorbing color screen, by Seares with the 60-inch reflecting telescope of the Mount Wilson Solar Observatory.

scarce. No one has given a satisfactory answer to this unless it be correct to say that these great globular clusters of stars, though extremely distant, are yet near at hand in comparison with the distances of the spirals. Ritchey's photograph of the great cluster in Hercules (Fig. 25) records fully 30,000 stars, and these are undoubtedly only the more brilliant members of the cluster. Still longer exposures might record 100,000 stars and yet leave unrecorded the fainter members of the cluster in vastly greater numbers. Shapley estimates the distance of this cluster, from several lines of investigation, as of the order of 100,000 light-years. Other great clusters have not been so thoroughly studied, but the available evidence concerning them is in harmony with the hypothesis of their great distances. Our own universe may be enormously more extensive than we see it because the outer stretches of it may be hidden by obstructing materials. If the obstructing materials consist chiefly of discrete particles whose diameters are large in comparison with the wave-lengths of light, we should expect the obstruction to be such as to reduce the brightness of distant objects without changing seriously the quality of their light.

The most elaborate structure yet proposed to explain the origin and development of the solar system is the planetesimal hypothesis by Chamberlin and Moulton. They postulate that the materials now composing the sun, planets and satellites, at one time existed as a spiral nebula, or as a great spiral swarm of discrete particles, each particle in elliptic motion about a central nucleus. The authors go further back and endeavor to account for the origin of spiral nebulæ, but it should be said that this phase of the subject is not vital to their hypothesis. It will happen once in a while, they say, that two massive stars will approach and pass each other closely. These stars will raise great tidal waves upon each other by their mutual attractions, and there will be outbursts of matter from each body, not only on that side of each which faces the other body, but on the opposite side of each, for somewhat the same reason that tidal waves in our oceans are raised on the side opposite the moon as well as on the side toward the moon. They assume that a great star traveling in what is now the principal plane of our solar system passed close to our sun when it was in an earlier stage of its existence; that a resulting disruption of

our sun led to the drawing out of solar materials in two opposing spiral branches; and that these materials in part, or for the most part, remained outside of the sun and in revolution about it, the whole composing a spiral nebula. The materials in the two branches of the spiral, the authors say, eventually combined into certain central

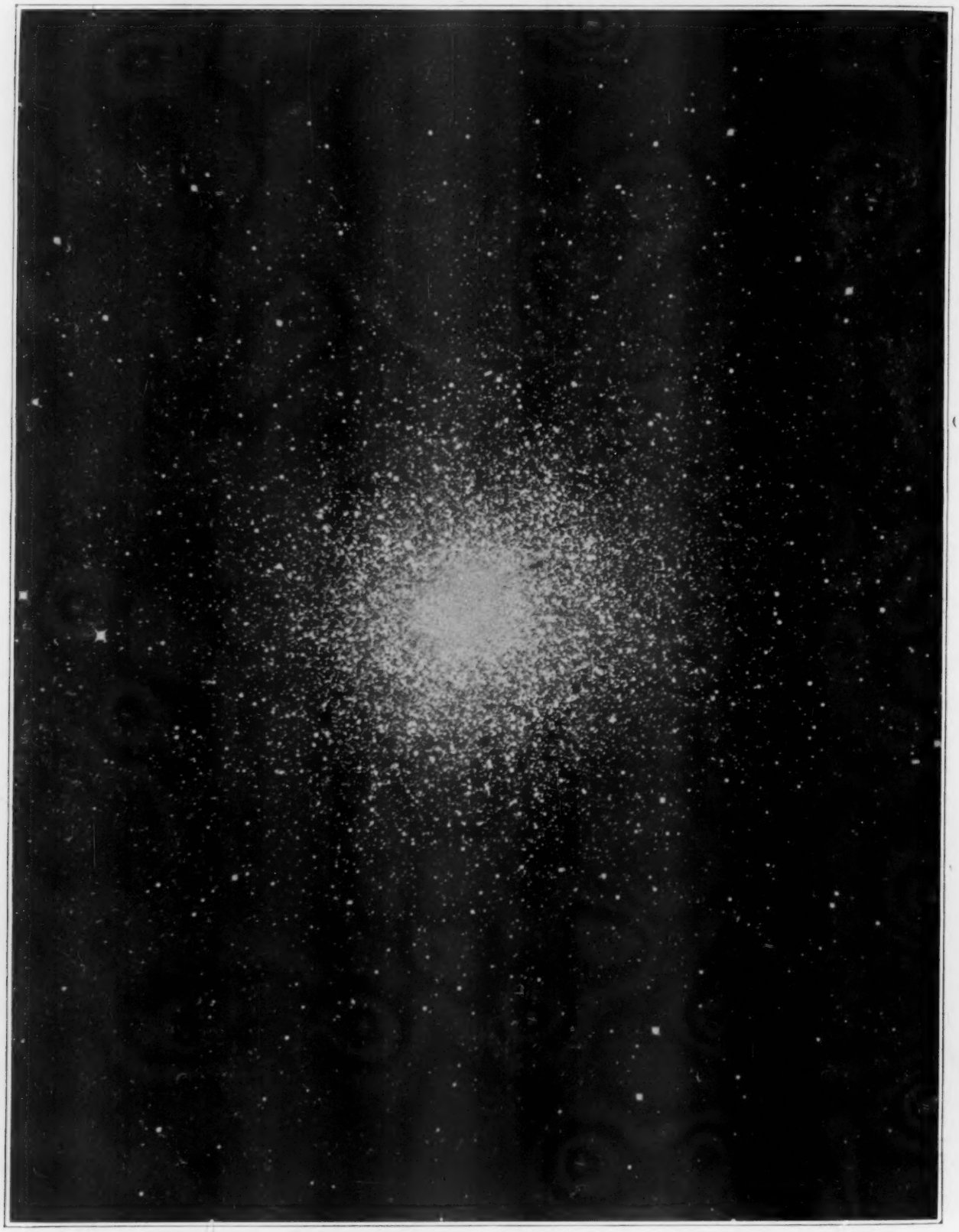


Fig. 25. The Great Star Cluster in Hercules, photographed by Ritchey with the 60-inch reflecting telescope of the Mount Wilson Solar Observatory.

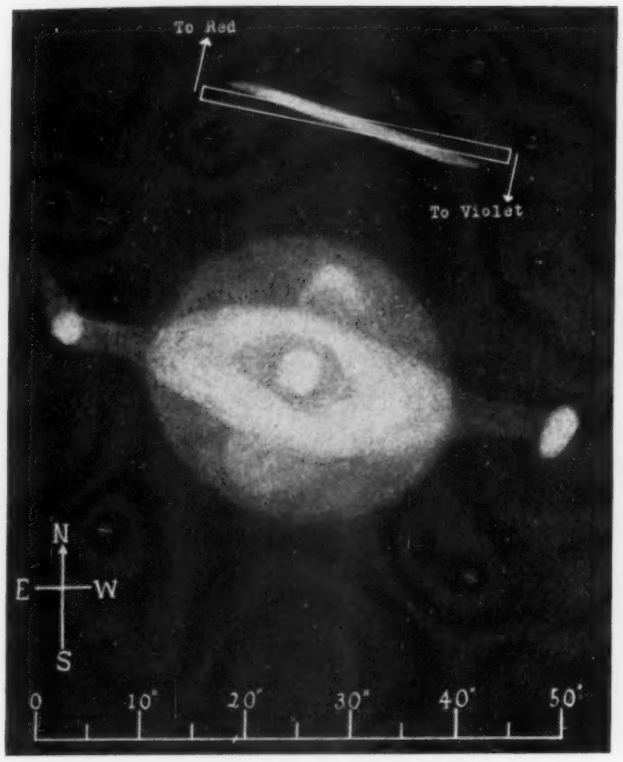


FIG. 26*a*. Planetary Nebula N.G.C. 7009. Composite drawing by Curtis from photographs made with the Crossley Reflector of the Lick Observatory. With the slit of a 3-prism spectrograph placed on the longer axis, the bright nebular lines were found to be inclined to the direction of the slit, owing to the rotation of the nebula, as shown (exaggerated) in the upper part of this figure, and as reproduced from the spectrogram in Fig. 26*b*.

masses, in accordance with the simple laws of physics, and the planets and their satellites of our system, as they exist to-day, are the result.

I see no reason to question that a spiral nebula could originate in this manner: the close passage of two massive stars could, in my opinion, produce an effect resembling a spiral nebula, quite in accordance with Moulton's test calculations on the subject. Some of the spirals have possibly been formed in this way; but that the tens of thousands of spirals have actually been produced in this manner is another question, and one which, in my opinion, is open to grave doubt. The distribution of the spirals seems to me to negative the idea. If the close approaches of pairs of stars are producing the spirals we should expect the spirals to occur and to exist preeminently in and near the Milky Way structure, for that is where the stars are; and that is precisely where we do not find the spirals.

I think it is more probable that our stellar system as a whole is a spiral nebula, or has analogies to a spiral nebula, and that our solar system has been formed from an insignificant detail of spiral structure, than that our sun and its system of planets and moons should be the evolved product of an entire spiral nebula. Of course we have not

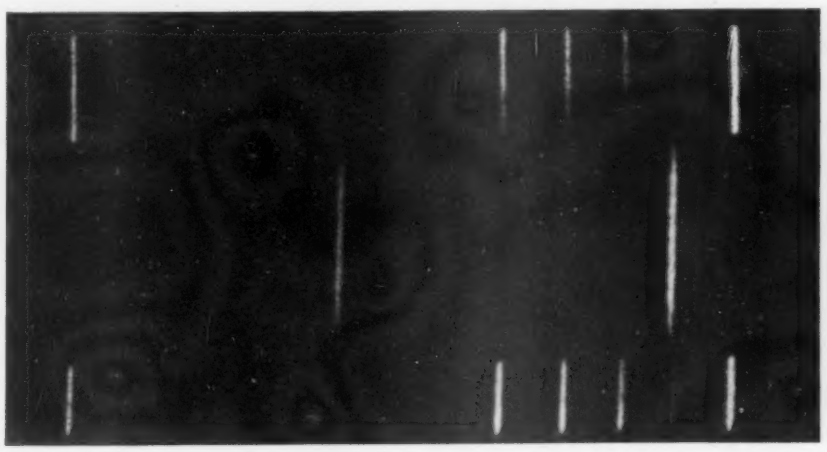


FIG. 26*b*. The First (right) and Second (left) Green Lines of Nebulium in the Spectrum of N.G.C. 7009.

[Enlargement approximately 20-fold. The six lines at the upper and lower edges of the figure are the reference spectrum of titanium.]

the proof of this; but the chances would appear to be strong that the ancestor of our solar system was a mass, nebulous or otherwise, comparatively diminutive in size.

There seems to be no reason to doubt the value of Herschel's opinion that a planetary nebula will develop into a star. Laplace's hypothesis that our solar system has

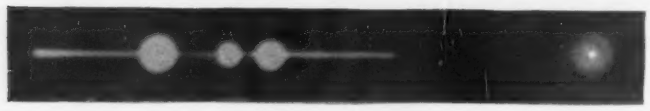


Fig. 27. Visual Image (right end) and Part of Visual Spectrum (left end) of the Planetary Nebula N.G.C.$_2$ 418.

[The horizontal line in the left half of the figure is a part of the continuous spectrum of the stellar nucleus of the nebula at the right end. Of the three white circles in the spectrum the left one is the hydrogen Beta image of the nebula 14 sec. of arc in diameter, the middle circle is the "second nebulium" green image of the nebula 9 sec. of arc in diameter; and the right one is the "first nebulium" green image of the nebula, 11 sec. of arc in diameter.]

developed from a small rotating nebula is still exceedingly valuable, but it has been so buffeted by the winds and waves of criticism that many of the details have had to be thrown overboard. I think we should give ourselves some assurance that certain of the planetary nebulæ may develop into systems bearing many resemblances to our solar system. Campbell and Moore have been able in the past year and a half to prove, by means of the spectrograph (see Figs. 26*a* and 26*b*), that these bodies are in rotation—just as we should expect them to be from their more or less symmetrical forms—around axes passing through their centers; these axes, in general, at right angles to their longest dimensions. The rotation of our sun and the revolution of our planets about the sun, all in one and the same direction and very nearly in the principal plane of the system, afford a close analogy.

The rotational velocities of the gases composing the principal rings in the planetary nebulæ are comparable with the orbital speeds of our great planets, Jupiter, Saturn, Uranus and Neptune; and the rotational speeds of the gases are slower and slower as we go out from the principal rings, which is true of the orbital speeds of the planets of our system.

It appears that there is very little material between the stellar nuclei and the principal rings of the planetaries. The material which we should normally expect to find there has apparently been drawn into the central stars. Very little material is left in that space to condense into planets, just as in our solar system the four inner planets, Mercury, Venus, earth and Mars, and the many asteroids, are of almost negligible mass. Jupiter and the other three outer planets contain 225 times as much matter as the earth and the other three inner planets and the more than 800 asteroids.

If we assume that the rotational speeds of the particles composing the rings and other outer structure of the planetary nebulæ are controlled by Newton's law of gravitation, we have means of estimating the masses of their central nuclei, or stars. The indications are extremely strong that the planetary nebulæ are in general at least as massive as our solar system: many times as massive in some cases, possibly less massive in others. In them we seem to have enough materials to develop into systems comparable in mass with our solar system.

More than twenty years ago I observed that the different gases composing several of the nebulæ are not uniformly distributed throughout the nebular structure. The hydrogen in some of the nebulæ that were

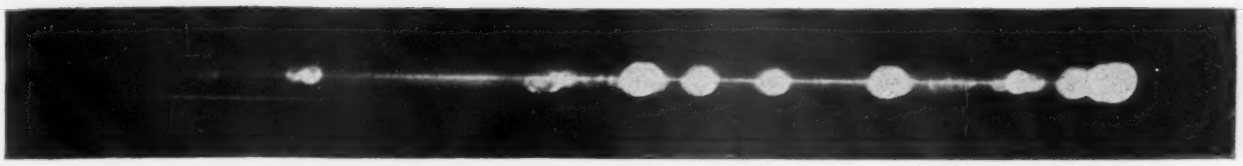


FIG. 28. The Spectrum of the Planetary Nebula N.G.C. 7662, photographed by Wright with the Draper slitless quartz spectrograph and the Crossley reflecting telescope of the Lick Observatory.

[The images of the nebula given by the radiations of different elements and different wave-lengths show a great variety of diameters and structural details. The two ellipses at the extreme right, strongly overlapping, are the two green nebulium images of the nebula. The adjoining smaller ellipse, slightly overlapping, is the hydrogen Beta image. The small images at the left end of the figure are far out in the ultra-violet region of the spectrum.]

critically examined was found to extend out farther than do the other chemical elements. Such was the case in the great Orion nebula, in the Trifid nebula, and in one of the small planetaries, N. G. C.$_2$ 418. Viewed in the telescope, the latter was observed to be a disc of greenish-blue light, about fourteen seconds of arc in diameter, with a well-defined star near the center of the disc. Viewed in the spectroscope, the spectrum of the central star was a continuous line of light, and the composite disc was resolved into three separate discs (see Fig. 27); the largest one of hydrogen, fourteen seconds of arc in diameter; a smaller one, corresponding to the first green line of the element nebulium, eleven seconds of arc in diameter; and a still smaller one, corresponding to the second line of nebulium, nine seconds of arc in diameter. The nebulium did not extend out so far from the central star as the hydrogen. Wolf and Burns applied photographic methods to a similar study of the Ring Nebula in Lyra, in 1908 and 1910, respectively, and found differences both in the sizes and in the detailed structure of the spectral rings. Wright has in the past two years carried the development of the subject much further, by photographic methods applied to the principal planetary nebulæ (see Fig. 28). He finds, for example, that the distribution of the helium in the structure of the planetary nebulæ always favors the central nucleus or star more than the hydrogen and nebulium distribution do. In some of the planetaries, the helium has apparently been drawn entirely into the central nucleus. In one of the planetaries the hydrogen globes seem to persist brilliantly after the nebulium images have become reduced in size, or have become exceedingly faint. We can scarcely doubt that in these phenomena we are witnessing certain stages of progress in the gradual evolution of the planetary nebulæ into the stars which we see at their centers, or, possibly, into systems of stars and planets. The materials, for the most part, seem to have been drawn —possibly are still moving—into the central stars, into suns that are forming; and a very little of the materials shown by observation to be revolving around the central suns may ultimately be left to form planets of the systems. Let us recall that in our own solar system 99 6/7 per cent. of the materials are in the sun, and that only one seventh of one per cent. of the materials exists outside of the sun, in the eight major planets and their moons.

The different sizes of the elliptic images of different chemical elements in the spectrum of a planetary nebula give some basis for the speculative thought that the chemical composition of the large outer planets of our solar system may be quite different from that of the small inner planets.

While a strong case can be made out for

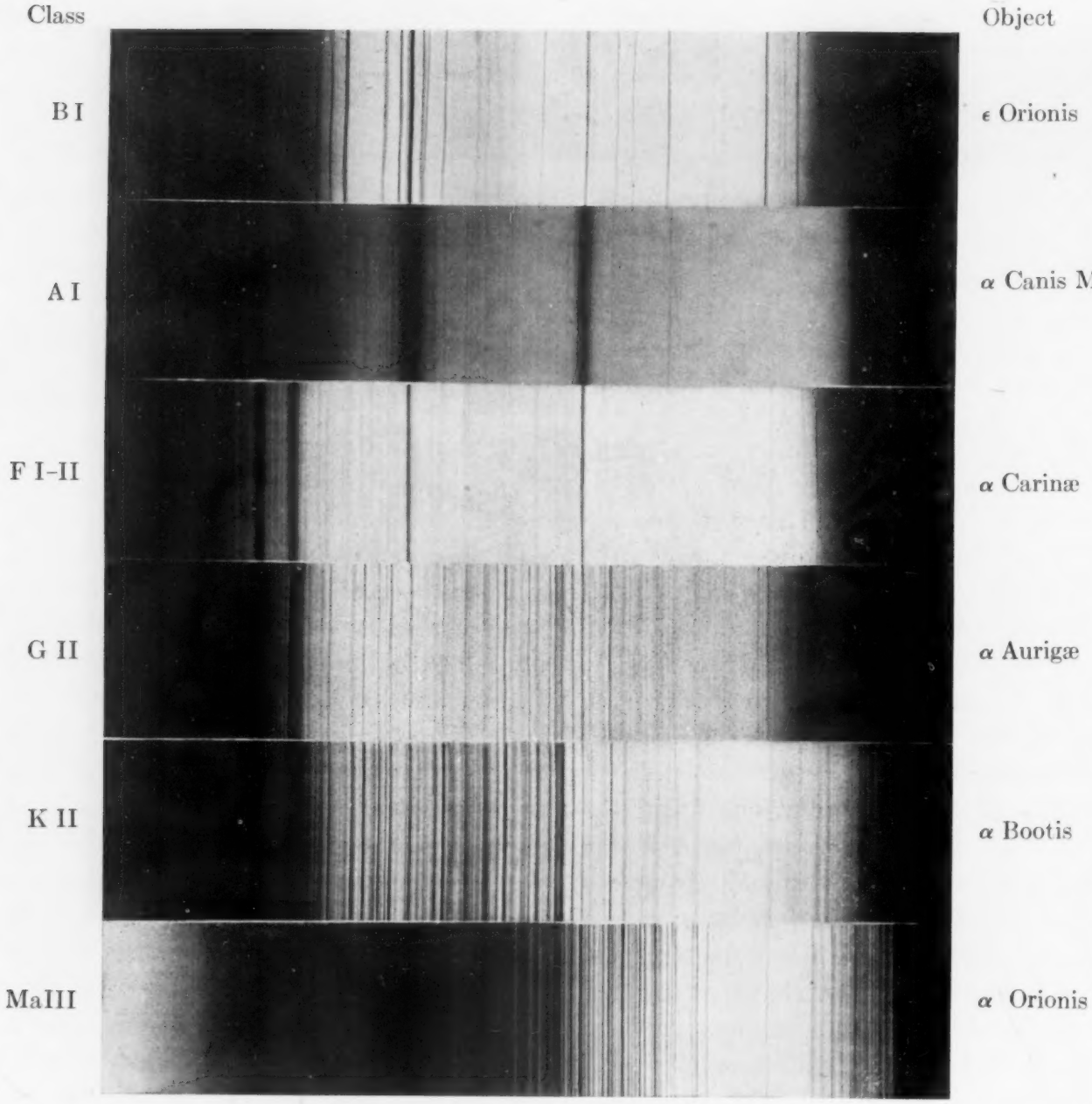


Fig. 29. Types of Stellar Spectra, Henry Draper Memorial, Harvard College Observatory.

the evolution of planetary nebulæ into stars at their centers, with possible planets revolving around them, we must not conclude that all stars have been formed from planetary nebulæ. There are reasons for rejecting that view.

1. Amongst the many millions of stars whose images have been examined in the telescopes or on photographic plates, fewer than 150 planetary nebulæ have been found. Unless the planetary-nebula stage of existence is lived very rapidly, the numbers are too few to play a controlling part in the development of stars in general at any point in stellar evolution.

2. The average speeds of the planetary nebulæ and of the different classes of stars are now fairly well defined. The average speed of the planetary nebulæ is about seven times that of the extremely blue stars, which are the only ones, we shall see later, that we need consider as the immediate descendants of the nebulæ. There are indeed individual stars which are traveling as rapidly as the individual planetary nebulæ, but on the average the discrepancy

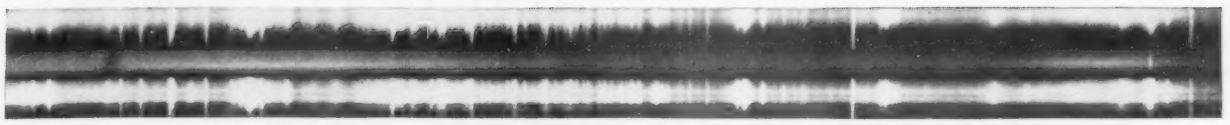


FIG. 30. The Spectrum of Alcyone, photographed by Wright with the Mills Spectrograph of the Lick Observatory.

[The star spectrum occupies the central horizontal section. The bright hydrogen Alpha line is one fourth inch from the right end, and the dark hydrogen Beta line is one half inch from the left end.]

seems entirely too great to let us conclude that the blue stars in general could have been formed from planetary nebulæ such as the 150 planetaries now known to us.

For the hypothesis that the stars in general have evolved from irregular nebulæ a vastly stronger case can be made.

In a priceless possession of astronomy, the Draper catalogue of stellar spectra, Harvard College Observatory has classified the spectra of a great many thousands of the brighter stars. They have been arranged in a sequence, running from the so-called extremely blue stars through the yellow stars to the red stars, which can be readily described. The main divisions are illustrated in Fig. 29. Each main class has ten subdivisions, but we need not dwell upon details. The dark lines in these spectra indicate the presence of certain vapors and gases of the chemical elements in the outer strata of the stars. In the Class *B* stars the helium lines rise to their maximum strength near the middle of the *B* subgroups and sink to insignificance in the later *B* or earlier *A* subdivisions, and the helium lines are not found at all in Class *F* and the later types. The hydrogen lines are fairly prominent in the Class *B* stars, but they increase to maximum intensity in Class *A*, and then decrease continuously throughout the remaining groups. The hydrogen lines are very inconspicuous in Class *M*, or red stars. The magnesium lines go up to a maximum in Class *A* and down to disappearance in the *F*'s and *G*'s. Some of the metallic lines, such as titanium and iron, usually begin to show in the later subdivisions of Class *A*, other metallic lines first enter upon the scene in Class *F*, and they increase in numbers and prominence up to a maximum in the red stars. The calcium lines are weak or entirely wanting in the Class *B*'s, and they increase in intensity as we pass down through the series, until they become the most prominent features in the spectra. We can not change the arrangement of these spectral classes without throwing the sequence of development of the spectral lines into hopeless disorder. This sequence is thought to represent the order of stellar evolution. A Class *B* star, according to that hypothesis, is a comparatively young star. It should develop, in the course of long ages, into an *F*, a *G*, a *K*, an *M*, and so on, to its final destination of darkness and invisibility.

Some of the Class *B* stars contain bright lines of hydrogen. Alcyone (Fig. 30) and Pleione, in the Pleiades, contain both bright

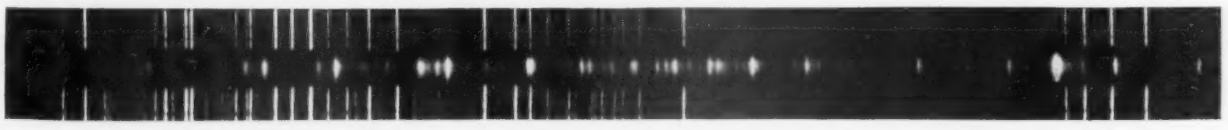


FIG. 31. The Spectrum of Eta Carinæ, photographed by Moore at the D. O. Mills Observatory Santiago, Chile.

[The series of bright lines above and below the star spectrum are the reference spectrum of iron.]

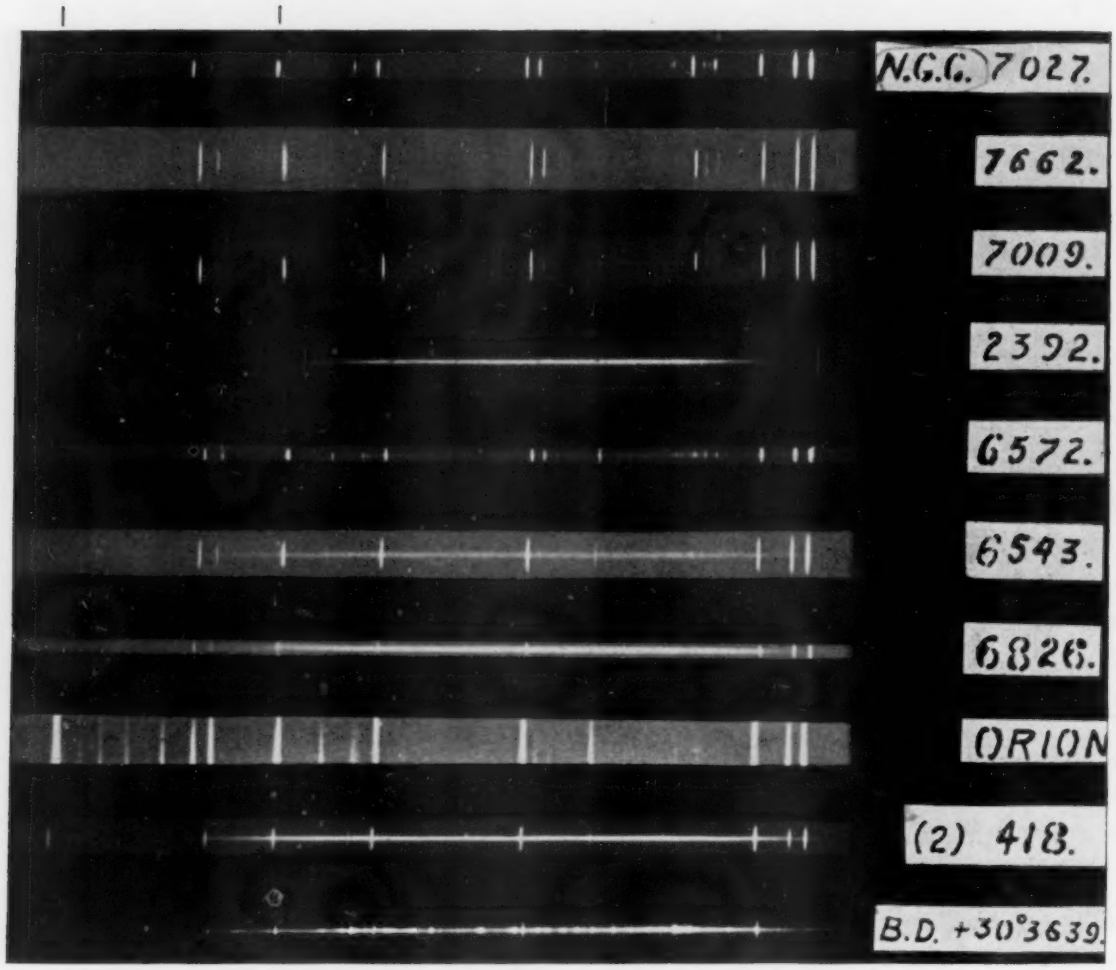


Fig. 32. Representative Spectra of Bright-line Nebulæ, photographed by Wright with the Mills spectrograph and 36-inch refracting telescope of the Lick Observatory.

and dark lines of hydrogen. There are hundreds of stars whose spectra contain a wide variety of bright lines and dark lines. Now and then a star's spectrum consists almost wholly of bright lines, as in the case of Eta Carinæ (Fig. 31). The bright lines in stellar spectra tell us that their stars contain extremely extensive atmospheres of the gases and vapors hydrogen, helium, and so on. A close relationship exists between the Class *B* stars, with and without bright lines, and a class of stars found extensively in the Milky Way structure whose spectra, containing many bright lines, are known as Wolf-Rayet spectra, after the discoverers of the first few stars in the class. Now, as Wright has shown, the central stars in the planetary nebulæ are of the Wolf-Rayet type (see Fig. 32, B.D + 30° 3639) in nearly all cases, and in other cases their spectra are closely related to Class *B* spectra (see Fig. 32, N.G.C. 2932). It has been shown, also chiefly by Wright, that the spectra of the nebulous parts of the planetary nebulæ have many points of connection with the spectra of their central stars. The spectra of the planetary nebulæ and the spectra of those large extended nebulæ (see Fig. 32, Orion, etc.) which give bright lines are essentially alike in character. The nebulium lines of the nebulæ have never been found to exist in any true star, no matter what its class, and we leave them out of account in this discussion; they do not in-

fluence our present question one way or the other. Aside from nebulium, the hydrogen and helium lines are the most prominent ones in the bright-line nebulæ. They are the most prominent ones in the nuclei of the planetary nebulæ. They are prominent in the isolated Wolf-Rayet stars, in the Class *B* stars containing bright lines, and in the

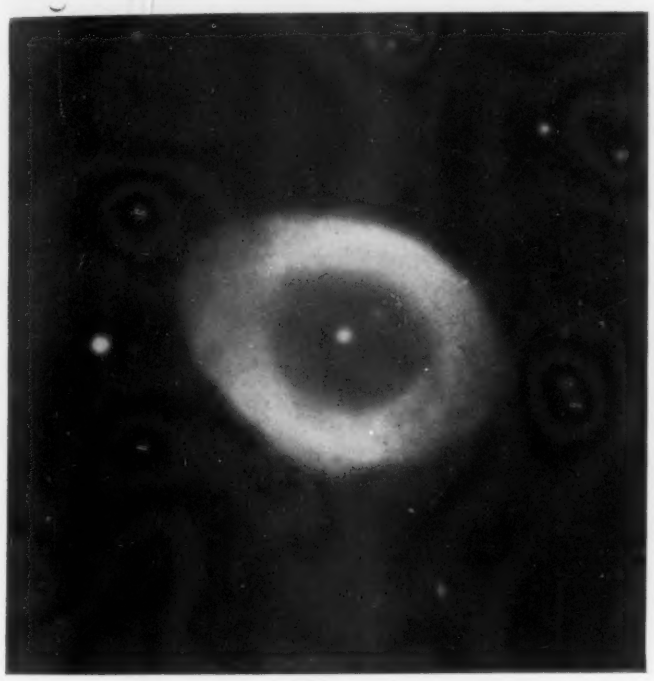


FIG. 33. The Ring Nebula in Lyra, photographed by Curtis with the Crossley Reflector of the Lick Observatory.

Class *B* stars containing only dark lines. Helium has never been found in any yellow or red stars, except feebly in a certain stratum of our sun's atmosphere, and that is due to our ability to observe our sun somewhat in detail; and the hydrogen is relatively feeble in the later classes of the Harvard sequence.

The continuous spectra of stars as arranged in the Harvard sequence decrease continuously in the relative strength of the blue, violet and ultra-violet regions as we pass from the central stars of the planetary nebulæ, which are wonderfully strong in ultra-violet light, down through the blue stars with both bright and dark lines, through the blue stars[6] containing dark lines only, and on through the yellow stars to the red stars. The central star in the ring nebula in Lyra (Fig. 33) is invisible to many inexperienced observers, even in the great Lick telescope. Yet it is so rich in violet light, and especially in ultra-violet light, that it can be photographed in the great reflecting telescopes with an exposure of only two or three seconds. Wright has recently made the interesting discovery that the continuous spectra of many planetary nebulæ are remarkably strong in a long stretch of the ultra-violet region. The sequence of decreasing richness in blue and violet light extends unbroken from the nebulæ and nebular nuclei down to the red stars.

The spectra of the stars are indicative of conditions existing in their surface strata. We do not know definitely just what conditions produce or accompany certain types of spectra, but surface temperature seems to be a prime influence, and there are some reasons for thinking that electrical conditions may also be extremely important. Now all determinations of the surface temperatures of the stars make the extreme blue-violet stars the hottest of all, with the effective temperatures decreasing continuously as we pass from the nuclear stars of the planetary nebulæ down through the Harvard sequence to the red stars. Fabry and his associates in Marseilles have recently arrived at the result, by physical methods, that the temperature of the Orion nebula is very high, vastly higher than the temperatures of the red and yellow stars,

[6] Huggins has called attention to a reduction in the brightness of the ultra-violet spectrum of the first-magnitude star Vega (Class *A*) by virtue of what seems to be an absorption band many hundred Angstrom units in width. It is not yet known to what extent the ultra-violet spectra of blue stars in general may be affected by such an absorption band.

and comparable with the temperatures of the blue stars. There again is a sequence with the nebulæ and the blue stars at one end and the red stars at the other.

Fowler has called attention to the remarkable facts that certain lines of helium, etc., requiring the most powerful electric discharges at command to produce them in the laboratory—super-spark lines, he calls them—are found in the greatest relative strength in the gaseous nebulæ; next in order of strength in the bright-line or Wolf-Rayet stars, which class includes the central stars of the planetary nebulæ; and in lesser strength in the first subdivision of the Class *B* stars, that is, in the bluest of the blue stars containing dark lines only; secondly, that the lines in the spectra of the later Class *B* stars, of the Class *A* and Class *F* stars are prevailingly those produced under the less intense conditions of the ordinary electric spark; and, thirdly, that the lines in the yellow-red stars are prevailingly the arc lines which indicate relatively weak electrical conditions. That is another sequence of conditions running from the nebulæ down to the red stars.

There are still other sequences running harmoniously through the Harvard classification. For example, the velocities of the stars in their travels within the stellar system increase as we pass by spectral classes from the large bright-line nebulæ and the very blue stars down through the yellow stars to the red stars. The distances apart of the two components of double stars, and consequently their periods of revolution

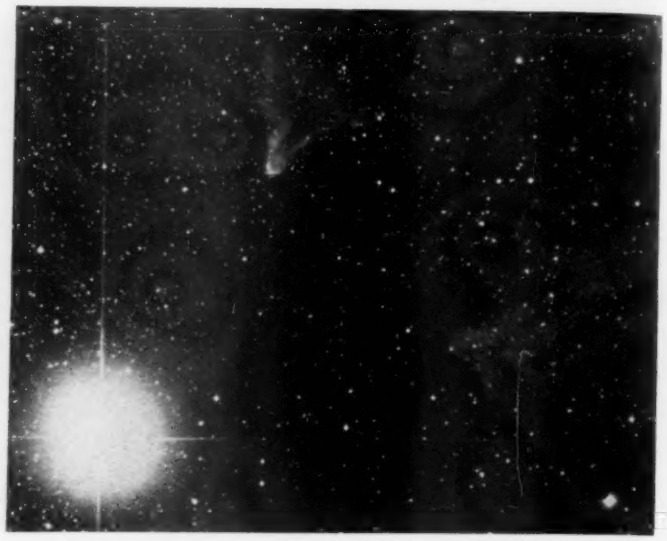


Fig. 34. The Irregular Nebulæ near Gamma Cassiopeiæ, photographed by Curtis with the Crossley Reflector of the Lick Observatory.

[The immensely over-exposed image of the brilliant star Gamma Cassiopeiæ is at the lower left-hand corner. The lines radiating from the center of the star image are diffraction effects produced within the telescope. The upper right half of the figure contains much nebulosity, the brighter angles of two nebular structures pointing approximately toward the star Gamma.]

around each other, increase consecutively as we pass from the blue stars to the red.

It might be said that, so far as all these stellar sequences are concerned, the course of evolution could begin with either the red stars or the blue stars and proceed to the other end of the sequence. Not to mention several very weighty objections to the assumption that the red stars are effectively young and the blue stars effectively old, we submit the case on the evidence of the nebulæ. The planetary nebulæ, the irregular nebulæ, the Wolf-Rayet stars, the Class *B* stars with bright lines, and the Class *B*

Fig. 35. The Spectrum of Gamma Cassiopeiæ, Henry Draper Memorial, Harvard College Observatory.

stars with dark lines are found prevailingly in and near the Galaxy. Pickering's study of the distribution of 6,106 of the brightest stars is summarized in the accompanying table.

GALACTIC LATITUDES OF STARS BRIGHTER THAN 6.25

Average Latitude	*B*	*A*	*F*	*G*	*K*	*M*	All
+62°.3.....	8	189	79	61	176	56	569
+41°.3.....	28	184	58	69	174	49	562
+21°.0.....	69	263	83	70	212	57	754
+ 9°.2.....	206	323	96	99	266	77	1,067
− 7°.0.....	161	382	116	84	239	45	1,027
−22°.2.....	158	276	117	100	247	69	967
−38°.2.....	57	161	94	59	203	59	633
−62°.3. ...	29	107	77	67	202	45	527
Sums.....	717	1,885	720	609	1,719	457	6,106
Means.....	90	236	90	76	215	57	763

The sky is divided into eight zones of equal areas, with the boundaries of the zones parallel to the galactic plane. The first line of figures contains the numbers of stars of the different spectral classes in the one eighth of the sky around the north pole of the Galaxy; the fourth and fifth lines the numbers in the zones containing the Galaxy, one zone adjoining the Milky Way on the north and the other on the south; and the last line the numbers of stars of the different classes in the eighth of the sky around the south pole of the Galaxy. If the stars of the different classes were uniformly distributed over the sky, the eight numbers in each vertical column would be equal. It is seen that the Class *B* stars are prevailingly in the Milky Way, and that the red stars of Class *M* are about uniformly distributed over the sky, though they are all in our stellar system.

The Class *B* stars and the stars containing bright lines are where the planetary and irregular nebulæ exist. Going further into detail: wherever there is a great nebulous region either in, or near, or outside of the Milky Way you will find the Class *B* and earlier types of stars abnormally plentiful; and the chances are fairly strong that some of the stellar spectra will contain bright lines. This is true of great regions in the Milky Way, it is true of the Orion and Pleiades regions, which we see at some distance outside of the Milky Way structure, though they are doubtless within our system. If you see a wisp of nebulosity near a bright star, look up the star's spectrum and you will probably find it an early Class *B*, as in the case of Gamma Cassiopeiæ, a second magnitude star, with nebulous structure near it (Fig. 34), whose spectrum contains both bright and dark lines of hydrogen and helium (Fig. 35). If you see an isolated bright star apparently enmeshed in an isolated patch of nebulosity, such as the one shown in Fig. 37, and the books say the star (*BD*–10°-4713) is yellow, or of Class *G*, communicate your suspicions that the books are mistaken about that star's spectrum to Professor Pickering, and he will probably reply that the star is in reality a very blue one, of early Class *B*. That is what happened a fortnight ago about this particular nebula and the star near its apparent center. If you find a red or yellow star of normal type, do not look for a nebula in apparent contact with it. Nebulæ and red stars do not coexist. You will find about the same number of red stars in the Milky Way that are visible in similar areas far from the Milky Way. You will find an occasional red star in the region of the Orion nebula and of other large nebulæ, but red stars will not appear there in greater numbers than their approximately uniform distribution over the sky requires.

The connection between the nebulæ and the bright-line stars, and between the nebulæ and the early Class *B* stars is close, both as to their types of spectra and as to their geometric distribution.

Do the nebulæ form stars or do the stars form nebulæ, or both? There is abundant

evidence that the catastrophes which produce new or temporary stars produce temporary nebulæ, for at a certain stage of their existence the temporary stars have nebular spectra; but in all cases thus far observed—as Adams has shown—the nebular spectrum quickly transforms itself into the Wolf-Rayet stellar spectrum. It is not impossible that the planetary nebulæ have in some cases resulted from the more violent catastrophes of distant space and time; that bodies originally stars may have been expanded under the heat of collision or other catastrophe to nebular conditions; but that an ultimate condensation will transform such nebulæ again into the stellar state, we can not doubt. That such nebulæ as those in the Pleiades (Fig. 13) or as the great Net-Work nebula in Cygnus (Fig. 36) were formed from stars can not be regarded with favor for a moment; but that the many Class *B* stars existing in those regions should have been formed from nebulous matter, and that others may be forming, implies an evolutionary process that is both natural and easy of comprehension. Transformation from star to nebula is abnormal, is *rev*olution, under the influence of catastrophe. Transformation from nebula to star is normal, is *ev*olution, under the continuous and regular operation of the simple laws of physics.

Fig. 36. The Net-work Nebula in Cygnus, photographed by Keeler with the Crossley Reflector of the Lick Observatory.

FIG. 37. The Milky Way, photographed by Barnard with the Bruce 10-inch telescope of the Yerkes Observatory.

[Of special interest is a small isolated nebula with a fifth magnitude star, BD — 10° 4713, near its center; nebula and star in the region poor in stars near the center of the photograph.]

Those who would suggest that the red stars[7] may be the young stars must start with stars uniformly distributed over the sky, and unassociated with nebulosity; and, transforming them through and past the red and yellow stages, must carry them prevailingly into the galactic regions, where, as Class *B*, or extremely blue stars, they

[7] This does not include the extremely red (Harvard Class *N*) stars. We refer to the 457 naked-eye red stars of Class *M* in Pickering's table, page 507, which are prevailingly the more massive members of their spectral class.

preferentially collect in the great nebulous areas, or, in many cases, become enmeshed in details of nebulous structure. We should pause long and consider well before embarking upon a voyage in that direction.

Long centuries of ignorance as to our surroundings gave way, finally, to the enlightening influence of the discovery of the place of the continents upon the earth, and of the place of our planet with respect to the sun. Working at peace and under extreme encouragement, the astronomers of to-day are learning the place of our star and its planets amongst the other stars. If the Magellanic Clouds, the greater globular star clusters, and the spiral nebulæ prove to be separate and independent systems, we shall bequeath to our successors the mighty problem of finding the place of our great stellar system amongst the host of stellar systems which stretch out through endless space.

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